

Design technology

First examinations 2009

Diploma Programme

Guide



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Design technology Guide

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International Baccalaureate Organization

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Diploma Programme
Design technology—guide

Published March 2007

Updated January 2010

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IBO mission statement

The International Baccalaureate Organization aims to develop inquiring, knowledgeable and caring young people who help to create a better and more peaceful world through intercultural understanding and respect.

To this end the IBO works with schools, governments and international organizations to develop challenging programmes of international education and rigorous assessment.

These programmes encourage students across the world to become active, compassionate and lifelong learners who understand that other people, with their differences, can also be right.

IB learner profile

The aim of all IB programmes is to develop internationally minded people who, recognizing their common humanity and shared guardianship of the planet, help to create a better and more peaceful world.

IB learners strive to be:

Inquirers	They develop their natural curiosity. They acquire the skills necessary to conduct inquiry and research and show independence in learning. They actively enjoy learning and this love of learning will be sustained throughout their lives.
Knowledgeable	They explore concepts, ideas and issues that have local and global significance. In so doing, they acquire in-depth knowledge and develop understanding across a broad and balanced range of disciplines.
Thinkers	They exercise initiative in applying thinking skills critically and creatively to recognize and approach complex problems, and make reasoned, ethical decisions.
Communicators	They understand and express ideas and information confidently and creatively in more than one language and in a variety of modes of communication. They work effectively and willingly in collaboration with others.
Principled	They act with integrity and honesty, with a strong sense of fairness, justice and respect for the dignity of the individual, groups and communities. They take responsibility for their own actions and the consequences that accompany them.
Open-minded	They understand and appreciate their own cultures and personal histories, and are open to the perspectives, values and traditions of other individuals and communities. They are accustomed to seeking and evaluating a range of points of view, and are willing to grow from the experience.
Caring	They show empathy, compassion and respect towards the needs and feelings of others. They have a personal commitment to service, and act to make a positive difference to the lives of others and to the environment.
Risk-takers	They approach unfamiliar situations and uncertainty with courage and forethought, and have the independence of spirit to explore new roles, ideas and strategies. They are brave and articulate in defending their beliefs.
Balanced	They understand the importance of intellectual, physical and emotional balance to achieve personal well-being for themselves and others.
Reflective	They give thoughtful consideration to their own learning and experience. They are able to assess and understand their strengths and limitations in order to support their learning and personal development.

Introduction

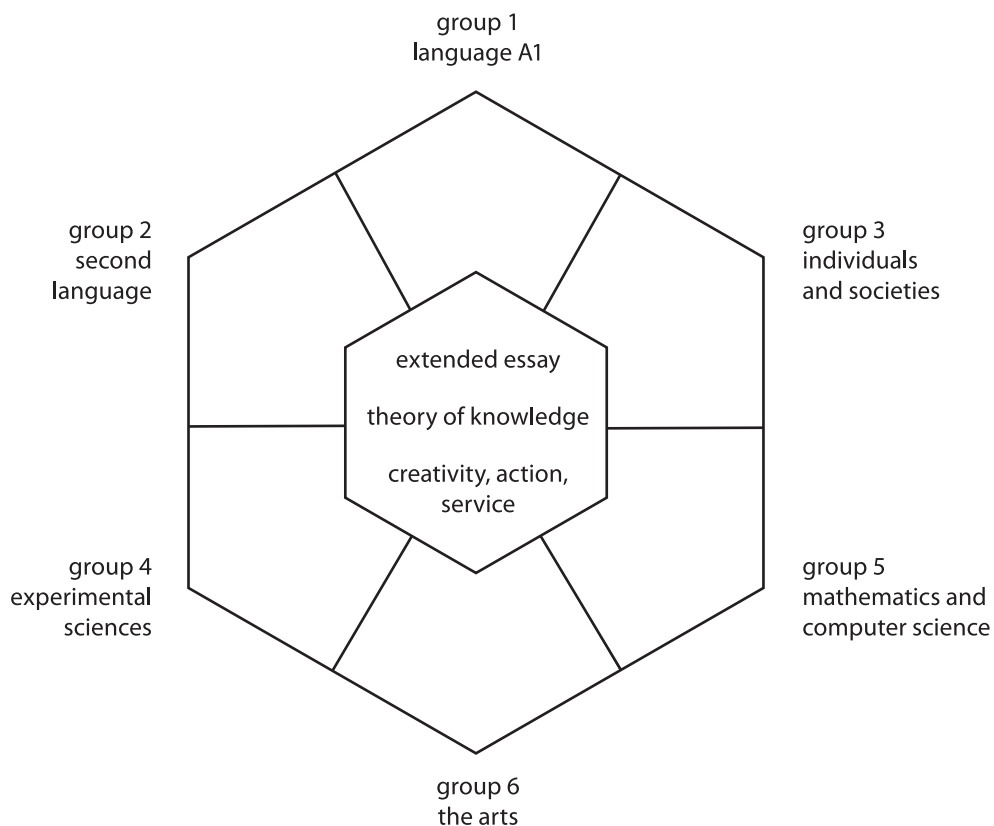
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The Diploma Programme

The Diploma Programme is a rigorous pre-university course of study designed for students in the 16 to 19 age range. It is a broad-based two-year course that aims to encourage students to be knowledgeable and inquiring, but also caring and compassionate. There is a strong emphasis on encouraging students to develop intercultural understanding, open-mindedness, and the attitudes necessary for them to respect and evaluate a range of points of view.

The Diploma Programme hexagon

The course is presented as six academic areas enclosing a central core. It encourages the concurrent study of a broad range of academic areas. Students study: two modern languages (or a modern language and a classical language); a humanities or social science subject; an experimental science; mathematics; one of the creative arts. It is this comprehensive range of subjects that makes the Diploma Programme a demanding course of study designed to prepare students effectively for university entrance. In each of the academic areas students have flexibility in making their choices, which means they can choose subjects that particularly interest them and that they may wish to study further at university.



Choosing the right combination

Students are required to choose one subject from each of the six academic areas, although they can choose a second subject from groups 1 to 5 instead of a group 6 subject. Normally, three subjects (and not more than four) are taken at higher level (HL), and the others are taken at standard level (SL). The IBO recommends 240 teaching hours for HL subjects and 150 hours for SL. Subjects at HL are studied in greater depth and breadth than at SL.

At both levels, many skills are developed, especially those of critical thinking and analysis. At the end of the course, students' abilities are measured by means of external assessment. Many subjects contain some element of coursework assessed by teachers. The course is available for examinations in English, French and Spanish.

The core of the hexagon

All Diploma Programme students participate in the three course requirements that make up the core of the hexagon. Reflection on all these activities is a principle that lies at the heart of the thinking behind the Diploma Programme.

The theory of knowledge (TOK) course encourages students to think about the nature of knowledge, to reflect on the process of learning in all the subjects they study as part of their Diploma Programme course, and to make connections across the academic areas. The extended essay, a substantial piece of writing of up to 4,000 words, enables students to investigate a topic of special interest that they have chosen themselves. It also encourages them to develop the skills of independent research that will be expected at university. Creativity, action, service (CAS) involves students in experiential learning through a range of artistic, sporting, physical and service activities.

The IBO mission statement and the IB learner profile

The Diploma Programme aims to develop in students the knowledge, skills and attitudes they will need to fulfill the aims of the IBO, as expressed in the organization's mission statement and the learner profile. Teaching and learning in the Diploma Programme represent the reality in daily practice of the organization's educational philosophy.

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Nature of group 4 subjects

Difference between SL and HL

Group 4 students at standard level (SL) and higher level (HL) undertake a common core syllabus, a common internal assessment (IA) scheme and have some overlapping elements in the options studied. They are presented with a syllabus that encourages the development of certain skills, attributes and attitudes, as described in the “Objectives” section of this guide.

While the skills and activities of group 4 subjects are common to students at both SL and HL, students at HL are required to study some topics in greater depth, to study additional topics and to study extension material of a more demanding nature in the common options. The distinction between SL and HL is one of breadth and depth.

Group 4 subjects and prior learning

Past experience shows that students will be able to study a group 4 subject at SL successfully with no background in, or previous knowledge of, the subject. Their approach to study, characterized by the specific IB learner profile attributes—inquirers, thinkers and communicators—will be significant here.

However, for most students considering the study of a group 4 subject at HL, while there is no intention to restrict access to group 4 subjects, some previous exposure to the specific group 4 subject would be necessary. Specific topic details are not specified but students who have undertaken the IB Middle Years Programme (MYP) or studied a relevant international GCSE subject would be well prepared. Other national technology education qualifications or a school-based science or technology course would also be suitable preparation for study of a group 4 subject at HL.

Group 4 subjects and the MYP

Students who have undertaken the MYP sciences, technology and mathematics courses will be well prepared for group 4 subjects. The MYP technology objectives and assessment criteria allow for a smooth transition from the MYP to Diploma Programme. In particular the “One world” objective in MYP sciences is further developed in group 4 with the increased emphasis on the general group 4 aim 8—that is, to “raise awareness of the moral, ethical, social, economic and environmental implications of using science and technology” (see the group 4 aims in the guides for biology, chemistry and physics).

Group 4 subjects and TOK

In looking at the ways of knowing described in the *Theory of knowledge guide* (March 2006), one could legitimately claim that design technology encompasses all these. Driven by emotion, using sense perception, enhanced by technology and combined with reason, it communicates through language, both textually and graphically.

The goal of technological knowledge is the improvement of the condition of humankind. The method of developing technological knowledge is design, but there is no single design method—it depends on the nature of the technological problem to be solved or the opportunity to be realized. The design method involves: the careful collection of data from many sources; a deep understanding of the design context; both convergent and divergent reasoning; innovation and creativity in the suggestion of outcomes; and modelling skills (graphical and three-dimensional) in the representation of the technology.

Technology is multidisciplinary, and so derives its knowledge from many sources. There is no set or defined body of technological knowledge. Relevant technological knowledge is only defined by the context of the problem or opportunity for which a technological solution is being sought. So designing, the methodology of technology, involves the seeking out of the knowledge that will facilitate a successful outcome. Some data and information may be collected and examined but later discarded because it does not progress the design process. During the guided collection of relevant knowledge, skills are developed that are applied to future technological problems. As the repertoire of skills becomes broader, individuals become more expert in understanding and developing technology.

Group 4 subjects and the international dimension

Technology itself is an international endeavour—the exchange of information and ideas around the world has been both a cause and an effect of the development of technology. This exchange is not a new phenomenon but it has accelerated in recent times with the development of information and communication technologies. Indeed, the idea that technology is a modern invention is a myth—people began developing technologies when they first started fashioning tools from stones, making fire to process their food, and shaping material to keep themselves warm. Teachers are encouraged to emphasize this contribution in their teaching of various topics, perhaps through an analysis of the principles of early technologies and the use of time-line web sites. The design technology method in its widest sense, with its emphasis on creativity, innovation, open-mindedness and freedom of thought, transcends politics, religion and nationality. Where appropriate within certain topics, the syllabus details sections in the group 4 guides contain assessment statements and teacher's notes illustrating the international aspects of technology.

On an organizational level, many international bodies now exist to analyse and promote technology. International bodies such as the International Labour Organization, the UN Industrial Development Organization, the UN Framework Convention on Climate Change, the UN Conference on Trade and Development and many others monitor, plan and provide information about global technology issues. The rapid profusion of these international organizations attests to the global nature of technology: both the internationalization of the design and development of technology, and the global effects of technologies, for example, climate change. Group 4 students are encouraged to access the extensive web sites of these international organizations to enhance their appreciation of the international dimensions of technology. Some topics in the group 4 guides are specifically written to bring out this global dimension. On a practical level, the group 4 project mirrors real technology by encouraging collaboration between schools across the regions.

The power of technology to transform societies is unparalleled. It has the potential to produce great universal benefits or to reinforce inequalities and cause harm to people and the environment. In line with the IBO mission statement, group 4 students need to be aware of the moral responsibility of designers to ensure that appropriate technologies are available to all communities on an equitable basis and that they have the technological capacity to use this for developing sustainable societies.

Curriculum model

A common curriculum model applies to all the Diploma Programme group 4 subjects: biology, chemistry, physics and design technology. Students at both SL and HL study a core syllabus, and this is supplemented by the study of options. Students at HL also study additional higher level (AHL) material.

However, there are some differences in this model for design technology and these arise from the design project, which is a unique feature of this subject. In design technology, students at both SL and HL study **one** option.

Design technology students at SL are required to spend 55 hours, and students at HL 81 hours, on practical/investigative work. This includes 28 hours on the design project at SL and 41 hours on the design project at HL. This also includes 10 hours for the group 4 project for both SL and HL. The design technology curriculum models are shown below.

SL design technology curriculum model

SL	Total teaching hours	150
Theory		95
	Core	65
	Options	30
Practical work		55
	Investigations	17
	Design project	28
	Group 4 project	10

HL design technology curriculum model

HL	Total teaching hours	240
Theory		159
	Core	65
	Additional higher level (AHL)	49
	Options	45
Practical work		81
	Investigations	30
	Design project	41
	Group 4 project	10

Format of the syllabus details

Note: The order in which the syllabus content is presented is not intended to represent the order in which it should be taught.

The format of the syllabus details section of the group 4 guides is the same for each subject. The structure is as follows.

Topics or options

Topics are numbered and options are indicated by a letter (for example, “Topic 3: Green design” or “Option D: Textiles”).

Sub-topics

Sub-topics are numbered and the estimated teaching time required to cover the material is indicated (for example, “3.2 Life cycle analysis (5 hours)”). The times are for guidance only and do not include time for practical/investigative work.

Assessment statements (AS)

Assessment statements, which are numbered, are expressed in terms of the outcomes that are expected of students at the end of the course (for example, “3.2.3 List the key stages in life cycle analysis”). These are intended to prescribe to examiners what can be assessed by means of the written examinations. Each one is classified as objective 1, 2 or 3 (see the “Objectives” section) according to the command terms used (see the “Command terms” section). The objective levels are relevant for the examinations and for balance within the syllabus, while the command terms indicate the depth of treatment required for a given assessment statement. It is important that students are made aware of the meanings of the command terms because these will be used in examination questions. (When the command term “define” is used, the word(s) or phrase to be defined is in italics.)

Teacher’s notes

Teacher’s notes, which are included alongside some assessment statements, provide further guidance to teachers.

Topic 1: Design process (10 hours) Topic or option

This topic introduces the design cycle model—a fundamental concept underpinning the design process and central to a student’s understanding of design activities. Each element of the design cycle represents how designers progress through the design process to refine the design solution in increasing detail. The topic then moves on to focus on the strategies that designers use to arrive at solutions to problems, and the varied nature of the skills and knowledge they need to carry out their activities successfully. The skills identified in this topic should be reflected in the internal assessment (IA) and reinforced throughout the course.

1.1 The design cycle model and the design process Sub-topic

3 hours

	Assessment statement	Obj	Teacher’s notes	
1.1.1	Describe how designers use design cycle models to represent the design process.	2	Design may be described in a variety of ways and degrees of complexity. Some design cycle models are simple and some are more complex. The design process usually consists of successive stages that can be arranged as a systematic cyclical process that eventually converges to produce a solution to a problem.	Assessment statement
1.1.2	List the stages in the IB design cycle model (DCM).	1	<p>The DCM comprises six stages, as follows:</p> <ul style="list-style-type: none"> identifying or clarifying a need or opportunity analysing, researching and specifying requirements generating ideas and solutions developing the chosen solution realizing the chosen solution testing and evaluating the chosen solution. 	Objective Teacher’s notes

Aims

Diploma Programme design technology aims to develop internationally minded people whose enhanced understanding of the technological world can facilitate our shared guardianship of the planet and create a better world.

Diploma Programme design technology achieves a high level of technological literacy by enabling students to develop critical-thinking and design skills, which they can apply in a practical context. While designing may take various forms, it will involve the selective application of knowledge within an ethical framework. It will focus on the design, development, analysis, synthesis and evaluation of problems, and their solution through practical activities. The creative tension between theory and practice is what characterizes design technology within the Diploma Programme experimental sciences.

It is in this context that the design technology course aims to develop in students:

1. a sense of curiosity as they acquire the skills necessary for independent and lifelong learning and action through inquiry into the technological world around them
2. an ability to explore concepts, ideas and issues with personal, local and global significance to acquire in-depth knowledge and understanding of design and technology
3. initiative in applying thinking skills critically and creatively to identify and resolve complex social and technological problems through reasoned ethical decision-making
4. an ability to understand and express ideas confidently and creatively using a variety of communication techniques through collaboration with others
5. a propensity to act with integrity and honesty, and take responsibility for their own actions in designing technological solutions to problems
6. an understanding and appreciation of cultures in terms of global technological development, seeking and evaluating a range of perspectives
7. a willingness to approach unfamiliar situations in an informed manner and explore new roles, ideas and strategies so they can articulate and defend their proposals with confidence
8. an understanding of the contribution of design and technology to the promotion of intellectual, physical and emotional balance and the achievement of personal and social well-being
9. empathy, compassion and respect for the needs and feelings of others in order to make a positive difference to the lives of others and to the environment
10. skills that enable them to reflect on the impacts of design and technology on society and the environment in order to develop their own learning and enhanced solutions to technological problems.

Objectives

The objectives for all group 4 subjects reflect those parts of the aims that will be assessed. Wherever appropriate, the assessment will draw upon environmental and technological contexts and identify the social, moral and economic effects of technology.

It is the intention of the design technology course that students achieve the following objectives.

1. Demonstrate an understanding of:
 - a. relevant facts and concepts
 - b. design and technological methods and techniques
 - c. technological terminology
 - d. methods of presenting technological information.
2. Apply and use:
 - a. relevant facts and concepts
 - b. design methods and technological techniques
 - c. technological terminology to communicate effectively
 - d. appropriate communication methods to present information.
3. Construct, analyse and evaluate:
 - a. design briefs, problems, specifications and plans
 - b. methods, techniques and products
 - c. data, information and technological explanations.
4. Demonstrate the personal skills of cooperation, perseverance, integrity and responsibility appropriate for effective designing.
5. Demonstrate the manipulative skills, processes and techniques necessary to carry out technological activity with precision and safety.

Note: The aims and objectives for design technology are different from the aims and objectives for the other group 4 subjects.

Command terms

These command terms indicate the depth of treatment required for a given assessment statement. These command terms will be used in examination questions, so it is important that students are familiar with the following definitions.

Objective 1

Define	Give the precise meaning of a word, phrase or physical quantity.
Draw	Represent by means of pencil lines.
Label	Add labels to a diagram.
List	Give a sequence of names or other brief answers with no explanation.
Measure	Find a value for a quantity.
State	Give a specific name, value or other brief answer without explanation or calculation.

Objective 2

Annotate	Add brief notes to a diagram or graph.
Apply	Use an idea, equation, principle, theory or law in a new situation.
Calculate	Find a numerical answer showing the relevant stages in the working (unless instructed not to do so).
Describe	Give a detailed account.
Distinguish	Give the differences between two or more different items.
Estimate	Find an approximate value for an unknown quantity.
Identify	Find an answer from a given number of possibilities.
Outline	Give a brief account or summary.

Objective 3

Analyse	Interpret data to reach conclusions.
Comment	Give a judgment based on a given statement or result of a calculation.
Compare	Give an account of similarities and differences between two (or more) items, referring to both (all) of them throughout.
Construct	Represent or develop in graphical form.
Deduce	Reach a conclusion from the information given.
Derive	Manipulate a mathematical relationship(s) to give a new equation or relationship.
Design	Produce a plan, simulation or model.
Determine	Find the only possible answer.
Discuss	Give an account including, where possible, a range of arguments for and against the relative importance of various factors, or comparisons of alternative hypotheses.
Evaluate	Assess the implications and limitations.
Explain	Give a detailed account of causes, reasons or mechanisms.
Predict	Give an expected result.
Show	Give the steps in a calculation or derivation.
Sketch	Represent by means of a graph showing a line and labelled but unscaled axes but with important features (for example, intercept) clearly indicated.
Solve	Obtain an answer using algebraic and/or numerical methods.
Suggest	Propose a hypothesis or other possible answer.

Assessment outline

SL design technology assessment specifications

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Component	Overall weighting (%)	Approximate weighting of objectives (%)		Duration (hours)	Format and syllabus coverage
		1+2	3		
Paper 1	20	20		$\frac{3}{4}$	30 multiple-choice questions on the core
Paper 2	24	12	12	1	Section A: one data-based question and several short-answer questions on the core (all compulsory) Section B: one extended-response question on the core (from a choice of three)
Paper 3	20	10	10	1	Several short-answer questions and extended-response questions in the option studied (all compulsory)
IA—investigations and group 4 project	18			27	Teacher choice—for investigations
IA—design project	18			28	Student choice

HL design technology assessment specifications

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Component	Overall weighting (%)	Approximate weighting of objectives (%)		Duration (hours)	Format and syllabus coverage
		1+2	3		
Paper 1	20	20		1	40 multiple-choice questions (± 15 common to SL plus about five more on the core and about 20 more on the AHL)
Paper 2	24	12	12	1¾	Section A: one data-based question and several short-answer questions on the core and the AHL (all compulsory) Section B: one extended-response question on the core and the AHL (from a choice of three)
Paper 3	20	10	10	1¼	Several short-answer questions and extended-response questions in the option studied (all compulsory)
IA—investigations and group 4 project	18			40	Teacher choice—for investigations
IA—design project	18			41	Student choice

In addition to addressing objectives 1, 2 and 3, the internal assessment scheme for both SL and HL addresses objective 4 (personal skills) using the personal skills criterion to assess the group 4 project, and objective 5 (manipulative skills) using the manipulative skills criterion to assess the design project. For both SL and HL, calculators are not permitted in paper 1 but are required in papers 2 and 3.

External assessment

The external assessment consists of three written papers.

Paper 1

Paper 1 is made up of multiple-choice questions that test knowledge of the core only for students at SL and the core and AHL material for students at HL. The questions are designed to be short, one- or two-stage problems that address objectives 1 and 2 (see the “Objectives” section). No marks are deducted for incorrect responses. Calculators are not permitted, but students are expected to carry out simple calculations.

Paper 2

Paper 2 tests knowledge of the core only for students at SL and the core and AHL material for students at HL. The questions address objectives 1, 2 and 3 and the paper is divided into two sections.

In section A, there is a data-based question that requires students to analyse a given set of data. The remainder of section A is made up of short-answer questions.

In section B, students at SL and HL are required to answer one question from a choice of three. These extended-response questions may involve writing a number of paragraphs, solving a substantial problem, or carrying out a substantial piece of analysis or evaluation. A calculator is required for this paper.

Paper 3

Paper 3 tests knowledge of the options and addresses objectives 1, 2 and 3. Students at SL and HL are required to answer several short-answer questions and extended-response questions in the option studied.

Practical work and internal assessment

General introduction

The internal assessment (IA), worth 36% of the final assessment, consists of an interdisciplinary project (the group 4 project), a mixture of short- and long-term investigations and the design project.

Student work is internally assessed by the teacher and externally moderated by the IBO. The performance in IA at both SL and HL is marked against assessment criteria, with each criterion having a maximum mark of 6.

Rationale for practical work

Although the requirements for IA are mainly centred on the assessment of practical skills, the different types of experimental work that a student may engage in serve other purposes, including:

- illustrating, teaching and reinforcing theoretical concepts
- developing an appreciation of the essential hands-on nature of design work
- developing an appreciation of the benefits and limitations of design methodology.

Practical scheme of work

The practical scheme of work (PSOW) is the practical course planned by the teacher and acts as a summary of all the investigative activities carried out by a student. SL and HL students in the same subject may carry out some of the same investigations.

Syllabus coverage

The range of investigations carried out should reflect the breadth and depth of the subject syllabus at each level, but it is not necessary to carry out an investigation for every syllabus topic. However, all students must participate in the group 4 project and the IA activities should ideally include a spread of content material from the core, option and, where relevant, AHL material. A minimum number of investigations to be carried out is not specified.

Choosing investigations

Teachers are free to formulate their own practical schemes of work by choosing investigations according to the requirements outlined. Their choices will be based on:

- subjects, levels and options taught
- the needs of their students
- available resources
- teaching styles.

Each scheme must include some complex investigations that make greater conceptual demands on the students. A scheme made up entirely of simple experiments, such as ticking boxes or exercises involving filling in tables, will not provide an adequate range of experience for students.

Teachers are encouraged to use the online curriculum centre (OCC) to share ideas about possible investigations by joining in the discussion forums and adding resources in the subject home pages.

Note: Any investigation or part investigation that is to be used to assess students should be specifically designed to match the relevant assessment criteria.

Flexibility

The IA model is flexible enough to allow a wide variety of investigations to be carried out covering a wide range of design activities.

The group 4 project

The group 4 project is an interdisciplinary activity in which all Diploma Programme science students must participate. The intention is that students from the different group 4 subjects analyse a common topic or problem. The exercise should be a collaborative experience where the emphasis is on the **processes** involved in scientific investigation rather than the **products** of such investigation.

In most cases all students in a school would be involved in the investigation of the same topic. Where there are large numbers of students, it is possible to divide them into several smaller groups containing representatives from each of the science subjects. Each group may investigate the same topic or different topics—that is, there may be several group 4 projects in the same school.

Practical work documentation

Details of an individual student's practical scheme of work are recorded on **form 4/PSOW** provided in section 4 of the *Vade Mecum*. Electronic versions may be used as long as they include all necessary information. In addition, the practical work corresponding to the best mark achieved by each student when assessed using the internal assessment criteria (planning, research, development and evaluation) and the instructions given by the teacher for the practical work and for the design project must be retained for possible inclusion in the sample work sent to an internal assessment moderator.

Time allocation for practical work

The recommended teaching times for all Diploma Programme courses are 150 hours at SL and 240 hours at HL. In design technology, students at SL are required to spend 55 hours, and students at HL 81 hours, on practical activities (excluding time spent writing up work). These times include 10 hours for the group 4 project. Only 2–3 hours of investigative work can be carried out after the deadline for submitting work to the moderator and still be counted in the total number of hours for the practical scheme of work.

Only some of the 55/81 hours of practical work need be allocated to the practical work that is assessed using the design technology IA criteria. Assessment using the design technology IA criteria will normally be done during the latter part of the course when students have become more familiar with the criteria and can be assessed in complex practical work.

Guidance and authenticity

All students should be familiar with the requirements for IA. It should be made clear to them that they are entirely responsible for their own work. It is helpful if teachers encourage students to develop a sense of responsibility for their own learning so that they accept a degree of ownership and take pride in their own work.

In responding to specific questions from students concerning investigations, teachers should (where appropriate) guide students into more productive routes of inquiry rather than respond with a direct answer. As part of the learning process, teachers can give general advice to students on a first draft of their work for IA. However, constant drafting and redrafting is not allowed and the next version handed to the teacher after the first draft must be the final one. This is marked by the teacher using the IA criteria. It is useful to annotate this work with the levels awarded for each aspect—"c" for complete, "p" for partial and "n" for not at all, to assist the moderator should the work be selected as part of the sample.

In assessing student work using the IA criteria, teachers should only mark and annotate the final draft.

When completing an investigation outside the classroom, students should work independently. Teachers are required to ensure that work submitted is the student's own. If any doubt exists, authenticity may be checked by one or more of the following methods.

- Discussion with the student
- Asking the student to explain the methods used and to summarize the results
- Asking the student to repeat the investigation

Teachers are required to sign the IA coversheet to confirm that the work of each student is his or her own unaided work.

Safety

While teachers are responsible for following national or local guidelines, which may differ from country to country, attention should be given to the mission statement below, which was developed by the International Council of Associations for Science Education (ICASE) Safety Committee.

ICASE Safety Committee

Mission statement

The mission of the ICASE Safety Committee is to promote good quality, exciting practical science, which will stimulate students and motivate their teachers, in a safe and healthy learning environment. In this way, all individuals (teachers, students, laboratory assistants, supervisors, visitors) involved in science education are entitled to work under the safest possible practicable conditions in science classrooms and laboratories. Every reasonable effort needs to be made by administrators to provide and maintain a safe and healthy learning

environment and to establish and require safe methods and practices at all times. Safety rules and regulations need to be developed and enforced for the protection of those individuals carrying out their activities in science classrooms and laboratories, and experiences in the field. Alternative science activities are encouraged in the absence of sufficiently safe conditions.

It is a basic responsibility of everyone involved to make safety and health an ongoing commitment. Any advice given will acknowledge the need to respect the local context, the varying educational and cultural traditions, the financial constraints and the legal systems of differing countries.

Internal assessment criteria

General information

The method of assessment used for internal assessment is criterion-related. That is to say, the method of assessment judges each student in relation to identified assessment criteria and not in relation to the work of other students.

The internal assessment component in all group 4 courses is assessed according to sets of assessment criteria and achievement level descriptors. The internal assessment criteria are for the use of teachers.

- For each assessment criterion, there are a number of descriptors that each describes a specific level of achievement.
- The descriptors concentrate on positive achievement, although for the lower levels failure to achieve may be included in the description.

Using the internal assessment criteria

Teachers should judge the internal assessment exercise against the descriptors for each criterion. The same internal assessment criteria are used for both SL and HL.

- The aim is to find, for each criterion, the descriptor that conveys most adequately the achievement level attained by the student. The process, therefore, is one of approximation. In the light of any one criterion, a student's work may contain features denoted by a high achievement level descriptor combined with features appropriate to a lower one. A professional judgment should be made in identifying the descriptor that approximates most closely to the work.
- Having scrutinized the work to be assessed, the descriptors for each criterion should be read, starting with level 0, until one is reached that describes an achievement level that the work being assessed does not match as well as the previous level. The work is, therefore, best described by the preceding achievement level descriptor and this level should be recorded. Only whole numbers should be used, not partial points such as fractions or decimals.
- The highest descriptors do not imply faultless performance and moderators and teachers should not hesitate to use the extremes, including zero, if they are appropriate descriptions of the work being assessed.
- Descriptors should not be considered as marks or percentages, although the descriptor levels are ultimately added together to obtain a total. It should not be assumed that there are other arithmetical relationships; for example, a level 2 performance is not necessarily twice as good as a level 1 performance.
- A student who attains a particular achievement level in relation to one criterion will not necessarily attain similar achievement levels in relation to the others. It should not be assumed that the overall assessment of the students will produce any particular distribution of scores.
- The assessment criteria should be available to students at all times.

Criteria and aspects

There are six assessment criteria that are used to assess the work of both SL and HL students.

- Planning—P
- Research—R
- Development—D
- Evaluation—E
- Manipulative skills—MS
- Personal skills—PS

The first four criteria—planning (P), research (R), development (D) and evaluation (E)—are each assessed twice, once during investigations and once in the design project.

Manipulative skills (MS) will be assessed once only and this is during the design project.

Personal skills (PS) will be assessed once only and this is during the group 4 project.

Each of the assessment criteria can be separated into three **aspects** as shown in the following sections. Descriptions are provided to indicate what is expected in order to meet the requirements of a given aspect **completely (c)** and **partially (p)**. A description is also given for circumstances in which the requirements are not satisfied, **not at all (n)**.

A “**complete**” is awarded 2 marks, a “**partial**” 1 mark and a “**not at all**” 0 marks.

The maximum mark for each criterion is 6 (representing three “completes”).

P	× 2 = 12
R	× 2 = 12
D	× 2 = 12
E	× 2 = 12
MS	× 1 = 6 (in design project)
PS	× 1 = 6 (in group 4 project)

This makes a total mark out of 60.

It will be submitted to IBCA as a mark out of 30 for the investigations (and the group 4 project) and a mark out of 30 for the design project. These will then be added together and scaled at IBCA to give a total out of 36%.

General regulations and procedures relating to IA can be found in the *Vade Mecum* for the year in which the IA is being submitted.

Planning

Levels/marks	Aspect 1	Aspect 2	Aspect 3
	Defining the problem	Formulating a brief or research question	Selecting variables or specifications
Complete/2	Identifies a focused problem for a design project or investigation.	States a detailed brief or research question that is appropriate to the level of study.	Selects and explains appropriate variables or specifications.
Partial/1	Identifies a suitable problem, but lacks detail in the explanation.	States a brief or research question, but this is not explained in detail.	Selects some appropriate variables or specifications.
Not at all/0	Does not identify a suitable problem or repeats the general aim provided by the teacher.	Does not state a brief or research question or the brief or research question is inappropriate.	Does not select appropriate variables or specifications.

Research

Levels/marks	Aspect 1	Aspect 2	Aspect 3
	Strategies	Data collection	Data processing and analysis
Complete/2	Identifies suitable strategies for research.	Collects appropriate research material.	Processes research material astutely with detailed analysis.
Partial/1	Identifies some relevant strategies.	Collects some useful research material.	Processes research material appropriately, though analysis is limited.
Not at all/0	Does not identify strategies or strategies are teacher-directed.	Does not collect any research material or the material is inappropriate.	Processes research material inappropriately.

Development

Levels/marks	Aspect 1	Aspect 2	Aspect 3
	Creativity	Techniques	Solution
Complete/2	Uses a range of innovative ideas to solve the problem.	Uses a wide range of appropriate techniques.	Arrives at a good solution to the problem.
Partial/1	Uses limited innovative ideas to solve the problem.	Uses a range of appropriate techniques.	Arrives at a satisfactory solution to the problem, but with aspects unresolved.
Not at all/0	Uses ideas that are mundane or irrelevant.	Does not use a range of techniques or techniques are inappropriate.	Arrives at an inappropriate solution to the problem or does not arrive at a solution.

Evaluation

Levels/marks	Aspect 1	Aspect 2	Aspect 3
	Conclusion	Procedure	Recommendations
Complete/2	Provides clear evidence of a valid conclusion that addresses the brief or research question.	Includes comprehensive evaluation of procedures at each stage of the investigation or project.	Makes realistic recommendations for improvement.
Partial/1	Provides a reasonable conclusion that makes reference to the brief or research question.	Includes limited evaluation of procedures.	Makes some useful recommendations for improvement.
Not at all/0	Provides no valid conclusion.	Includes no evaluation of procedures or procedures are teacher-directed.	Makes no valid recommendations for improvement.

Manipulative skills (used only for assessing the design project)

This criterion addresses objective 5.

Levels/marks	Aspect 1	Aspect 2	Aspect 3
	Procedures	Use of equipment and materials	Techniques
Complete/2	Is able to adhere to procedures for carrying out practical work in a precise, methodical manner.	Manipulates materials and equipment with skill and pays due attention to the safety factors.	Is able to master a wide range of techniques for practical tasks.
Partial/1	Is able to adhere to procedures for carrying out practical work but overlooks some aspects.	Manipulates materials and equipment to complete the task in a safe manner.	Is able to master a variety of techniques for practical tasks but within narrow parameters.
Not at all/0	Is unable to adhere to procedures for carrying out practical work or requires constant guidance from the teacher.	Is unable to manipulate materials and equipment satisfactorily or safely.	Is able to deal with a limited range of techniques for practical tasks.

See "The group 4 project" section for the personal skills criterion.

Clarifications of the IA criteria

Planning

Aspect 1: defining the problem

Students should be given the opportunity to explore open-ended problems. The need or opportunity for formulating a suitable design brief or research question should be identified and fully explained. A particular design context will normally offer a variety of potential problems to solve.

Although the general aim of the investigation may be given by the teacher, students must identify a focused problem for themselves. It is not sufficient for a student merely to restate the research question provided by the teacher. Teachers must not tell students the intended outcome of the investigation or project.

Aspect 2: formulating a brief or research question

Having explored the design context, students will need to formulate a brief for a project or a research question for an investigation. The brief or research question needs explanation or justification. A project brief will explain the nature of the intended outcome and the target market. A research question will be justified in relation to the design context. For example, a question that states that the investigation concerns testing a range of timbers to compare their properties is not as good as one that relates the question to the appropriate selection of timbers based on their properties for a floor covering, for which the criteria for selection of a suitable timber will be explained.

Aspect 3: selecting variables or specifications

Having formulated their own brief or research question, students will select appropriate variables for an investigation or specifications for a project. Variables are factors that can be measured and/or controlled. Independent variables are those that are manipulated, and the result of this manipulation leads to the measurement of the dependent variable. A controlled variable is one that should be held constant so as not to obscure the effect of the independent variable on the dependent variable.

The initial design specification for a project needs to be explained in relation to the design brief, and priorities for research and development should be stated. The specifications should be justified as a list of requirements against which ideas will be evaluated and the final outcome assessed.

Research

Aspect 1: strategies

A variety of sources for collection of suitable data should be identified and priorities made clear. Research for the project or investigation should anticipate the collection of sufficient data so that the brief or research question can be suitably addressed. Research may take many forms depending on the design context chosen.

Aspect 2: data collection

For a design project, there should be a balance between qualitative and quantitative data collection, and between primary and secondary data. Investigations may be focused on strategies for collection of one particular category of data, usually quantitative. Data may be presented in a variety of forms, for example, tables, graphs or photographs, and so on.

Aspect 3: data processing and analysis

In a design project, research material will form the basis for generation of ideas. Analysis of data that has been suitably processed should relate the usefulness of the research material to the design brief or research question. Errors or uncertainties should be identified where appropriate, and the effect on the reliability of the data quantified. Students should show that they can take raw data, transform it and present it in a form suitable for analysis.

Development

Aspect 1: creativity

Students should demonstrate originality in tackling the project or investigation. When addressing this criterion, teachers will need to ensure that projects and investigations have enough scope for innovation.

Aspect 2: techniques

Techniques should be chosen that are appropriate to the task and provide evidence of innovative ideas. This may be in the form of detailed drawings, models (physical and/or CAD), tests, experiments, and so on.

Aspect 3: solution

The final solution needs to be described in appropriate detail. The solution may be the result of an experiment or the use of the design process to design a product or system. For a design project, the detailing must be sufficient for the solution to be realized, with materials and manufacturing techniques made explicit. Formal drawings should be produced in an appropriate format.

Evaluation

Aspect 1: conclusion

The validity of the solution to the problem should be evaluated and justified. Evidence may be provided via testing of a designed product and expert appraisal or astute interpretation of data for an investigation, even if the conclusion appears contradictory to the accepted theories.

Aspect 2: procedure

The suitability of chosen strategies at each stage of the investigation or project should be assessed taking into account available resources, including time. Students should not only state weaknesses, but also indicate how significant the weaknesses are. For a design project, procedures will also relate to testing the solution in relation to the specifications stated at the planning stage and gaining user research.

Aspect 3: recommendations

Suggestions for improvements should be based on the weaknesses and limitations identified in aspect 2. Improvements may be presented in a variety of forms, such as drawings, a modified design specification, or a new set of variables. For investigations based on data collection, modifications should address issues of precision, accuracy and reproducibility of the results. The modifications proposed should be realistic and clearly described. It is not sufficient to state that more precise equipment should be used or more time allocated. Modifications for a designed prototype should consider changes to the design for scaling up production and to produce a design family of products.

Manipulative skills

This criterion relates to the design project only for assessment purposes.

Aspect 1: procedures

The procedures for practical work should be conducted in a methodical manner to aid the finishing of the final outcome. Practical work should have been planned in advance so as to show clearly the sequence of operations to be carried out. Equipment, materials and estimates of time allowance for each operation should be stated clearly if students are to be able to work to plan.

Aspect 2: use of equipment and materials

The level of guidance required will depend on the nature of the activity and experience of the students. Health and safety must be given due consideration at all times, with explicit evidence apparent in the documentation. Evidence of manipulative skills should be clear from a diary of manufacture. Photographs of the final outcome should be evident in the evaluation section of the report.

Aspect 3: techniques

A variety of techniques will be relevant to the task. Students should have made astute judgments concerning resource issues for completing the investigation or project. Materials, components and equipment must be manipulated to a standard that will allow a detailed evaluation.

The use of ICT in design technology

In common with the other group 4 subjects, design technology aims to develop and apply the students' information and communication technology (ICT) skills in the study of the subject. The use of ICT is encouraged in practical work throughout the course whether the investigations and projects are assessed using the IA criteria or otherwise.

Section A: use of ICT in assessment

The word processing of IA investigations and projects should be encouraged so as to develop students' presentation skills and knowledge of new design applications. A typical IA document should include a variety of presentation techniques, which may include text, graphs, diagrams and photographs.

Planning

Students may use ICT in order to justify their chosen problem/investigation by examining some existing products or by conducting some market research. Market research could be presented in tables or graphs and the user needs identified and summarized. Issues that need to be investigated could be presented in a table with suggested sources, which will enable the student to gather reliable data. The following is an example.

Issues for investigation	Primary data	Secondary data
Size of users	Measure a range of possible users	www.ergonomics4schools.co.uk Peoplesize 2000 (computer software) produced by Open Ergonomics Ltd. Pheasant, S. 1996. <i>Bodyspace: Anthropometry, Ergonomics and the Design of Work</i> . Taylor & Francis.
Materials and manufacturing methods	Photograph existing products	Norman, E, Urry, S, Cubitt, J, Whittaker, M. 2000. <i>Advanced Design and Technology</i> . Longman. Focus on plastics (computer software) produced by Focus Educational Software Ltd.

Research

ICT should be used appropriately so as to aid students in their gathering of data or presentation of work. Students should be encouraged to convert and edit raw data so that it can be presented in tables, graphs, diagrams and photographs. Data presented using ICT should be annotated and sources clearly identified.

The Internet allows students to gather a wide range of data, but finding a reliable source can be very time-consuming and perhaps less appropriate than a primary source. Students should use ICT to collect and edit data from the Internet, questionnaires, CD-Roms, spreadsheets, databases and digital imagery.

Development

Students will not be expected to digitize hand-drawn sketches and other development work. However, the use of computer-aided design (CAD) to aid development and manufacture should also be evident. Formal dimensioned drawings should be produced using CAD systems. Formal drawings could be in the form of textile patterns, orthographic projection, electronic systems and printed circuit board (PCB) diagrams.

Evaluation

Evidence of testing should be presented using digital photographs.

Manipulative skills

The planning of manufacture or other activities should use ICT where appropriate. The use of Gantt charts, flow diagrams and sequence diagrams should be encouraged. Evidence of practical activities should be in the form of an annotated photographic diary, whereas any changes or improvements to formal drawings could be supported by an ongoing evaluation. Evidence of two- and three-dimensional (2D and 3D) modelling should be in the form of digital images. Proof of the final project outcome should also be presented in a digital format.

The use of data-logging software

Data-logging software may be used in investigations assessed using the IA criteria provided that the following principle is applied.

The student's contribution to the investigation must be evident so that this alone can be assessed by the teacher. This student's contribution can be in the selection of settings used by the data-logging and graphing equipment, or can be demonstrated in subsequent stages of the investigation.

(When data logging is used, raw data is defined as any data produced by software and extracted by the student from tables or graphs to be subsequently processed by the student.)

Use of data-logging software is appropriate with respect to assessment if the student decides and inputs most of the relevant software settings.

With some software, the same investigation could be carried out with little or no student input, and as such would be inappropriate for assessment.

Section B: use of ICT in non-assessed practical work

It is not necessary to use ICT in assessed investigations but students will be required to use each of the following software applications at least once during the course.

- Software for graph plotting
- Computer modelling software
- CAD
- The Internet and CD-Roms to gather research data
- A spreadsheet for data processing

The use of each of the above five ICT applications by students would be authenticated by means of entries in the students' practical scheme of work, form 4/PSOW. For example, if a student used a spreadsheet in an investigation, this should be recorded on form 4/PSOW. Any other applications of ICT can also be recorded on form 4/PSOW.

The group 4 project

Summary of the group 4 project

The group 4 project is a collaborative activity where students from different group 4 subjects work together on a scientific or technological topic, allowing for concepts and perceptions from across the disciplines to be shared. This is to encourage an understanding of the relationships between scientific disciplines and the overarching nature of the scientific method. The project can be practically or theoretically based. Collaboration between schools in different regions is encouraged.

The group 4 project allows students to appreciate the environmental, social and ethical implications of science and technology. It may also allow them to understand the limitations of scientific study, for example, the shortage of appropriate data and/or the lack of resources. The emphasis is on interdisciplinary cooperation and the processes involved in scientific investigation, rather than the products of such investigation.

The choice of scientific or technological topic is open but the project should clearly address the group 4 aims 7, 8 and 10 of the biology, chemistry and physics subject guides.

Ideally, the project should involve students collaborating with those from other group 4 subjects at all stages. To this end, it is not necessary for the topic chosen to have clearly identifiable separate subject components. However, for logistical reasons some schools may prefer a separate subject “action” phase (see the following “Project stages” section).

Project stages

The 10 hours allocated to the group 4 project, which are part of the teaching time set aside for IA, can be divided into three stages: planning, action and evaluation.

Planning

This stage is crucial to the whole exercise and should last about two hours.

- The planning stage could consist of a single session, or two or three shorter ones.
- This stage must involve all group 4 students meeting to “brainstorm” and discuss the central topic, sharing ideas and information.
- The topic can be chosen by the students themselves or selected by the teachers.
- Where large numbers of students are involved, it may be advisable to have more than one mixed subject group.

After selecting a topic or issue, the activities to be carried out must be clearly defined before moving from the planning stage to the action and evaluation stages.

A possible strategy is that students define specific tasks for themselves, either individually or as members of groups, and investigate various aspects of the chosen topic. At this stage, if the project is to be experimentally based, apparatus should be specified so that there is no delay in carrying out the action stage. Contact with other schools, if a joint venture has been agreed, is an important consideration at this time.

Action

This stage should last around six hours and may be carried out over one or two weeks in normal scheduled class time. Alternatively, a whole day could be set aside if, for example, the project involves fieldwork.

- Students should investigate the topic in mixed subject groups or single subject groups.
- There should be collaboration during the action stage; findings of investigations should be shared with other students within the mixed/single subject group. During this stage, in any practically based activity, it is important to pay attention to safety, ethical and environmental considerations.

Note: Students studying two group 4 subjects are not required to do two separate action phases.

Evaluation

The emphasis during this stage, for which two hours is probably necessary, is on students sharing their findings, both successes and failures, with other students. How this is achieved can be decided by the teachers, the students or jointly.

- One solution is to devote a morning, afternoon or evening to a symposium where all the students, as individuals or as groups, give brief presentations.
- Alternatively, the presentation could be more informal and take the form of a science fair where students circulate around displays summarizing the activities of each group.

The symposium or science fair could also be attended by parents, members of the school board and the press. This would be especially pertinent if some issue of local importance has been researched. Some of the findings might influence the way the school interacts with its environment or local community.

Addressing aims 7 and 8

Note: Although the aims of design technology are not identical to the other group 4 subjects, it is the following group 4 aims that are referred to when describing the interdisciplinary group 4 project undertaken by all group 4 students.

Aim 7—“develop and apply the students’ information and communication technology skills in the study of science”.

Aim 7 may be partly addressed at the planning stage by using electronic communication within and between schools. It may be that ICT (for example, data logging, spreadsheets, databases, and so on) will be used in the action phase and certainly in the presentation/evaluation stage (for example, use of digital images, presentation software, web sites, digital video, and so on).

Aim 8—“raise awareness of the moral, ethical, social, economic and environmental implications of using science and technology”.

The choice of topic should enable one or more elements of aim 8 to be incorporated into the project.

Addressing the international dimension

There are also possibilities in the choice of topic to illustrate the international nature of the scientific endeavour and the increasing cooperation required to tackle global issues involving science and technology. An alternative way to bring an international dimension to the project is to collaborate with a school in another region.

Types of project

While addressing aims 7, 8 and 10 the project must be based on science or its applications.

The project may have a hands-on practical action phase or one involving purely theoretical aspects. It could be undertaken in a wide range of ways.

- Designing and carrying out a laboratory investigation or fieldwork.
- Carrying out a comparative study (experimental or otherwise) in collaboration with another school.
- Collating, manipulating and analysing data from other sources, such as scientific journals, environmental organizations, science and technology industries and government reports.
- Designing and using a model or simulation.
- Contributing to a long-term project organized by the school.

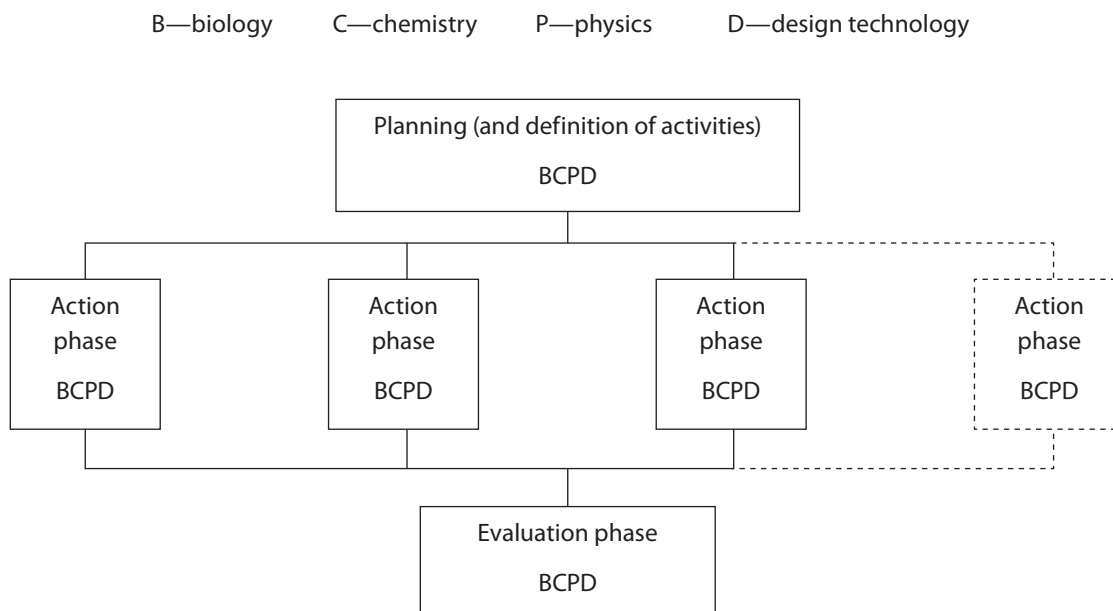
Logistical strategies

The logistical organization of the group 4 project is often a challenge to schools. The following models illustrate possible ways in which the project may be implemented.

Models A, B and C apply within a single school, and model D relates to a project involving collaboration between schools.

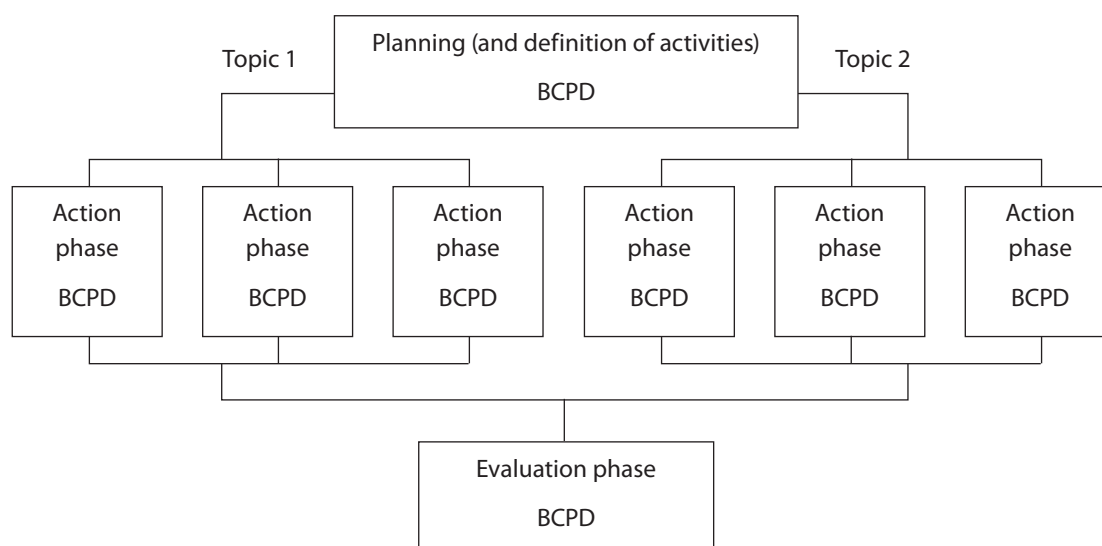
Model A: mixed subject groups and one topic

Schools may adopt mixed subject groups and choose one common topic. The number of groups will depend on the number of students. The dotted lines in the model show the addition of more groups as student numbers increase.



Model B: mixed subject groups adopting more than one topic

Schools with large numbers of students may choose to do more than one topic.



Model C: single subject groups

For schools opting for single subject groups with one or more topics in the action phase, simply replace the mixed subject groups in model A or B with single subject groups.

Model D: collaboration with another school

The collaborative model is open to any school. To this end, the IBO will provide an electronic collaboration board on the OCC where schools can post their project ideas and invite collaboration from another school. This could range from merely sharing evaluations for a common topic to a full-scale collaborative venture at all stages.

For schools with few diploma students or schools with certificate students, it is possible to work with non-Diploma Programme or non-group 4 students or undertake the project once every two years. However, these schools are encouraged to collaborate with another school. This strategy is also recommended for individual students who may not have participated in the project, for example, through illness or because they have transferred to a new school where the project has already taken place.

Timing

The 10 hours that the IBO recommends be allocated to the project may be spread over a number of weeks. The distribution of these hours needs to be taken into account when selecting the optimum time to carry out the project. However, it is possible for a group to dedicate a period of time exclusively to project work if all/most other school work is suspended.

Year 1

In the first year, students' experience and skills may be limited and it would be inadvisable to start the project too soon in the course. However, doing the project in the final part of the first year may have the advantage of reducing pressure on students later on. This strategy provides time for solving unexpected problems.

Year 1–year 2

The planning stage could start, the topic could be decided upon, and provisional discussion in individual subjects could take place at the end of the first year. Students could then use the vacation time to think about how they are going to tackle the project and would be ready to start work early in the second year.

Year 2

Delaying the start of the project until some point in the second year, particularly if left too late, increases pressure on students in many ways: the schedule for finishing the work is much tighter than for the other options; the illness of any student or unexpected problems will present extra difficulties. Nevertheless, this choice does mean students know one another and their teachers by this time, have probably become accustomed to working in a team and will be more experienced in the relevant fields than in the first year.

Combined SL and HL

Where circumstances dictate that the project is only carried out every two years, HL beginners and more experienced SL students can be combined.

Selecting a topic

Students may choose the topic or propose possible topics, with the teacher then deciding which one is the most viable based on resources, staff availability, and so on. Alternatively, the teacher selects the topic or proposes several topics from which students make a choice.

Student selection

Students are likely to display more enthusiasm and feel a greater sense of ownership for a topic that they have chosen themselves. A possible strategy for student selection of a topic, which also includes part of the planning stage, is outlined here. At this point, subject teachers may provide advice on the viability of proposed topics.

- Identify possible topics by using a questionnaire or a survey of students.
- Conduct an initial “brainstorming” session of potential topics or issues.
- Discuss, briefly, two or three topics that seem interesting.
- Select one topic by consensus.
- Students make a list of potential investigations that could be carried out. All students then discuss issues such as possible overlap and collaborative investigations.

Assessment

The group 4 project is to be assessed for the personal skills criterion only and this will be the only place where this criterion is assessed. It is up to the school how this assessment takes place.

Note: The group 4 project is not to be used for the assessment of the other criteria.

Personal skills (for group 4 project assessment only)

This criterion addresses objective 4.

Levels/marks	Aspect 1	Aspect 2	Aspect 3
	Self-motivation and perseverance	Working within a team	Self-reflection
Complete/2	Approaches the project with self-motivation and follows it through to completion.	Collaborates and communicates in a group situation and integrates the views of others.	Shows a thorough awareness of their own strengths and weaknesses and gives thoughtful consideration to their learning experience.
Partial/1	Completes the project but sometimes lacks self-motivation.	Exchanges some views but requires guidance to collaborate with others.	Shows limited awareness of their own strengths and weaknesses and gives some consideration to their learning experience.
Not at all/0	Lacks perseverance and motivation.	Makes little or no attempt to collaborate in a group situation.	Shows no awareness of their own strengths and weaknesses and gives no consideration to their learning experience.

The assessment can be assisted by the use of a student self-evaluation form, but the use of such a form is not a requirement.

The design project

Introduction

The design project, which unifies all aspects of the design technology course, is based on the design cycle and is a compulsory element of the practical course of work and assessment.

The syllabus for HL has more breadth than that for SL, with **41** hours allocated to the design project as distinct from **28** hours at SL. It is expected, therefore, that HL students should develop a greater knowledge and skill base than SL students, and should demonstrate this through the design project.

Project summary report

Each student must submit a project summary report, which identifies the key stages of the project development. The report may contain information in the form of text, diagrams, photographs, and so on, and should explain the process followed and the decisions taken.

Assessment

The design project **must** be assessed against the design technology criteria: planning, research, development, evaluation and manipulative skills.

Nature of the subject

To design with technology is to use human ingenuity in selected activities in order to meet needs and find solutions. This can be achieved through existing or new technologies. Design consists of gathering information about the problem or opportunity, processing that information, and planning for some kind of intervention either by modifying what is already there or by introducing something new. The designer is interested not just in the material environment but also in the social, technological, economic, environmental, political, legislative and ethical considerations that affect people's priorities.

The intent of the course

Diploma Programme design technology is based on a model of learning that incorporates knowledge, skills and design principles in problem-solving contexts, while at the same time maximizing the use of local and readily available resources. It assumes no previous experience in either technology or design. The intent is not solely the acquisition of knowledge about design and technology, which may change or become outdated, but it is about learning how to adapt to new experiences and to approach problems with the appropriate skills and the relevant techniques to identify the important elements and, crucially, to develop the optimum solutions. The **design cycle** is at the core of the course, and it is expected that students will use this process in the practical investigative work as well as in the theory. Each element in the design cycle represents an aspect of design technology, which, when viewed together, constitutes a holistic approach. Any given element is therefore only to be seen in the context of the whole process.

Design technology within group 4

Technology relies on the laws and properties of nature and the accumulated knowledge of technology to create new products, techniques and systems. Design technology sits comfortably in the Diploma Programme experimental sciences, because the design cycle involves inquiry, and students need to study scientific principles in order to understand advances made in society and to be able to speculate what might be achieved in the future.

The range of syllabus topics has been chosen to ensure a balance and interest for all students regardless of their gender and previous experience. It includes options that will be attractive to all students, not only those whose future studies will be in the field of science, technology or engineering, and it offers opportunities for in-depth studies of relevant technological issues for those who will study such subjects.

The design cycle and group 4

The design cycle to technology is the equivalent of the scientific method to science. The emphasis is therefore on using the design cycle to solve a problem or to realize an opportunity using relevant information and production techniques. Practical and/or investigative work centres on developing skills and ideas, the properties of materials, mechanisms, control systems and production techniques, as they apply to constructing a product or system.

Design technology as a complement to the arts

The majority of students will have little or no experience of formal courses in technology at the start of the Diploma Programme. Consequently, standard level (SL) design technology is ideally suited to the non-science specialist. It can be used as a bridge between the sciences and the designed world around us. It might be seen as “a spectrum, with ideas at one end and techniques and things at the other, with design as the middle term” (Edwin Layton, 1974, “Technology as Knowledge” in *Technology and Culture*, Vol 15, No 1, pp 37–38). Design technology is concerned with people’s needs and what they regard as important. The politics of society, and the cultural, aesthetic and artistic needs and values are given due status. In addition, environmental considerations are given significant emphasis. The subject is strongly connected with social issues, making informed choices, and differentiating between information and misinformation in technology. Students are encouraged to study the technologies in different cultures and to understand the forces that have shaped their development. The course is not solely about “high technology” (sophisticated, industrialized, mass production) but also includes the appropriateness of technologies for societies. Diploma Programme design technology emphasizes good technological design, how to exercise judgment and responsibility in the use of technology, how to recognize needs, how to explore a range of conflicting demands, and how to produce the optimum solution.

Design technology interfaces well between the sciences and the arts, using principles from both in the design cycle.

Design technology for the scientist or engineer

Where students may be considering a university or college course in science, applied science, technology, product design or engineering, the standard level (SL) and higher level (HL) courses may be taken in conjunction with any other course in group 4. Diploma Programme design technology then provides such students with the opportunity to deal with realistic problems and to synthesize appropriate solutions using the processes practised during the course, in particular through the design project.

Overview of course structure

Core syllabus topics are based on the study of course concepts such as the design process, product design, green design and product innovation, as well as knowledge of materials, product development and evaluation strategies. Through their study of the core topics, students will appreciate how these topics interact and overlap with each other depending on the design context and the viewpoints of the designer, manufacturer and consumer. Additional higher level (AHL) topics examine in more detail technological knowledge relating to the practical function of products, their methods of manufacture, and designing for a sustainable future.

Students are only required to study **one** option topic for examination in paper 3. Option topics are based on 30 hours teaching at SL and 45 hours at HL. This allows for more in-depth treatment of the topics than in the previous course (two shorter options studied) and allows more time for development of practical work. Options have been chosen to offer a wide range of choices and to allow schools to give a particular focus to their course depending on resources and curriculum development.

Possible teaching approaches

There are many approaches that can be taken, and the syllabus is written in a non-prescriptive way so that the facilities and the location of schools will not be the deciding factor in successfully teaching the course.

The processes at work in design technology activities involve the continual iteration of students' ideas between the issues that are being solved and the proposals that are being developed (practical tests, drawings and models) for the solution.

It is a dynamic process of clarification—reflective and active—which involves thinking and doing. The subject requires students to experience practical, experimental, investigative and project work in the workshop or classroom. This needs to be hands-on and not solely taught by demonstration.

Time is allowed in the course to enable the theory to be integrated with practical work experiments and investigations. The length and frequency of these experiments and investigations have not been specified, so that teachers may adapt the course to their particular human and physical resources. The processes involved in design and problem solving are complex: short practical investigations lasting over one or two classes can be used to exemplify aspects of the process in addition to the project. No specific period of the course is stipulated for the design project, but it is reasonable to consider undertaking it in the second year where sufficient syllabus content has been covered to allow acquired skills and knowledge to be used. The option may be taught after the other parts of the course, or it may be integrated into the teaching of other topics at various stages in the course.

Resource requirements

The main emphasis of the course is on the design process and the design cycle, not the hardware required in manufacturing artifacts. For schools new to the subject, the equipment and consumables required by this course will vary from school to school and will depend very much on the option chosen for study. Schools currently teaching design technology should choose the option that suits their facilities, equipment and expertise. Computers, and access to the Internet, open up further resource avenues rich in materials relevant for design technology.

Syllabus overview

The syllabus for the Diploma Programme design technology course is divided into three parts: the core, the AHL material and the options.

	Teaching hours
Core	65
Topic 1: Design process	10
Topic 2: Product innovation	7
Topic 3: Green design	9
Topic 4: Materials	17
Topic 5: Product development	11
Topic 6: Product design	5
Topic 7: Evaluation	6
AHL	49
Topic 8: Energy	9
Topic 9: Structures	10
Topic 10: Mechanical design	8
Topic 11: Advanced manufacturing techniques	10
Topic 12: Sustainable development	12
Options SL and HL	30/45
Option A: Food science and technology	30/45
Option B: Electronic product design	30/45
Option C: CAD/CAM	30/45
Option D: Textiles	30/45
Option E: Human factors design	30/45

Students at SL and HL are required to study one option from A–E.
The duration of each option is 30 hours at SL and 45 hours at HL.

Syllabus outline

	Teaching hours
Core	65
Topic 1: Design process	10
1.1 The design cycle model and the design process	3
1.2 Generating ideas	2
1.3 Communicating ideas	5
Topic 2: Product innovation	7
2.1 Designers and the product cycle	2
2.2 Invention and innovation	3
2.3 People and markets	2
Topic 3: Green design	9
3.1 Principles of green design	2
3.2 Life cycle analysis	5
3.3 Strategies for green design	2
Topic 4: Materials	17
4.1 Introducing and classifying materials	1
4.2 Properties of materials	3
4.3 Timber	3
4.4 Metals	3
4.5 Plastics	3
4.6 Ceramics	2
4.7 Composites	2
Topic 5: Product development	11
5.1 Manufacturing techniques	1.5
5.2 Craft production	1.5
5.3 Mechanization	2
5.4 Automation	2
5.5 Economic considerations	2
5.6 Clean manufacturing	2
Topic 6: Product design	5
6.1 Ergonomics	2
6.2 The designer and society	3
Topic 7: Evaluation	6
7.1 Evaluation and designing	2
7.2 Evaluation and manufacturing	2
7.3 Evaluation and the consumer	2

	Teaching hours
AHL	49
Topic 8: Energy	9
8.1 Historical overview	3
8.2 Types of energy: economic, environmental and political aspects	3
8.3 Case studies	3
Topic 9: Structures	10
9.1 Young's modulus—stress and strain	2
9.2 Forces	2
9.3 The strength and stiffness of structures	3
9.4 Beams	3
Topic 10: Mechanical design	8
10.1 General concepts	4
10.2 Mechanical motion	2
10.3 Conversion of motion	2
Topic 11: Advanced manufacturing techniques	10
11.1 Joining	2
11.2 Moulding	3
11.3 Casting	3
11.4 Forming	2
Topic 12: Sustainable development	12
12.1 Appropriate technology and sustainable development	4
12.2 Sustainable building design	8
Options SL and HL	30/45
Option A: Food science and technology	30/45
Core (SL and HL)	30
A1 Development of the food industry	4
A2 Designing new food products	2
A3 Nutrition, balanced diet and health	6
A4 Food spoilage and food preservation	4
A5 Food science	2
A6 Food processing	3
A7 Food packaging and distribution	3
A8 People and food—lifestyles	3
A9 Issues and responsibilities	3
Extension (HL only)	15
A10 Food poisoning	5
A11 Genetically modified organisms and food production	5
A12 Food security	5
Option B: Electronic product design	30/45
Core (SL and HL)	30
B1 General principles	6
B2 Digital logic	5
B3 Control	2

		Teaching hours
B4	Operational amplifiers	6
B5	Programmable interface controllers	5
B6	Communication systems	4
B7	Global standards for digital electronic products	2
Extension (HL only)		15
B8	The smart home	5
B9	Disposal of electronic products	5
B10	Converging technologies	5
Option C: CAD/CAM		30/45
Core (SL and HL)		30
C1	The impact of CAD on the design process	6
C2	CAM systems	8
C3	The impact of CAD/CAM on manufacturing	5
C4	Rapid prototype manufacture	6
C5	CAD/CAM products	5
Extension (HL only)		15
C6	Materials	3
C7	Robots	6
C8	Social, moral, economic and environmental aspects	6
Option D : Textiles		30/45
Core (SL and HL)		30
D1	Raw materials	4
D2	Fabric manufacturing and finishing techniques	5
D3	Evolution of textile processing	2
D4	Designing textiles with CAD	3
D5	Manufacturing textiles with CAM	2
D6	Medical products	3
D7	Recreational products	2
D8	Transportation products	2
D9	Markets	4
D10	Silk	3
Extension (HL only)		15
D11	Smart clothing and wearable computing	5
D12	Sustainability in the textile industry	5
D13	Cotton and the “EU Flower”: case study of an ecolabel	5
Option E: Human factors design		30/45
Core (SL and HL)		30
E1	Human factors design	3
E2	Human factors data	4
E3	Research and testing	3
E4	Modelling	3
E5	Health and safety legislation	3
E6	Design for usability	2
E7	Contexts	12
Extension (HL only)		15
E8	Digital humans	3
E9	Design for disability	6
E10	Design for purpose	4
E11	Beyond usability—designing for pleasure	2

Syllabus details—Core

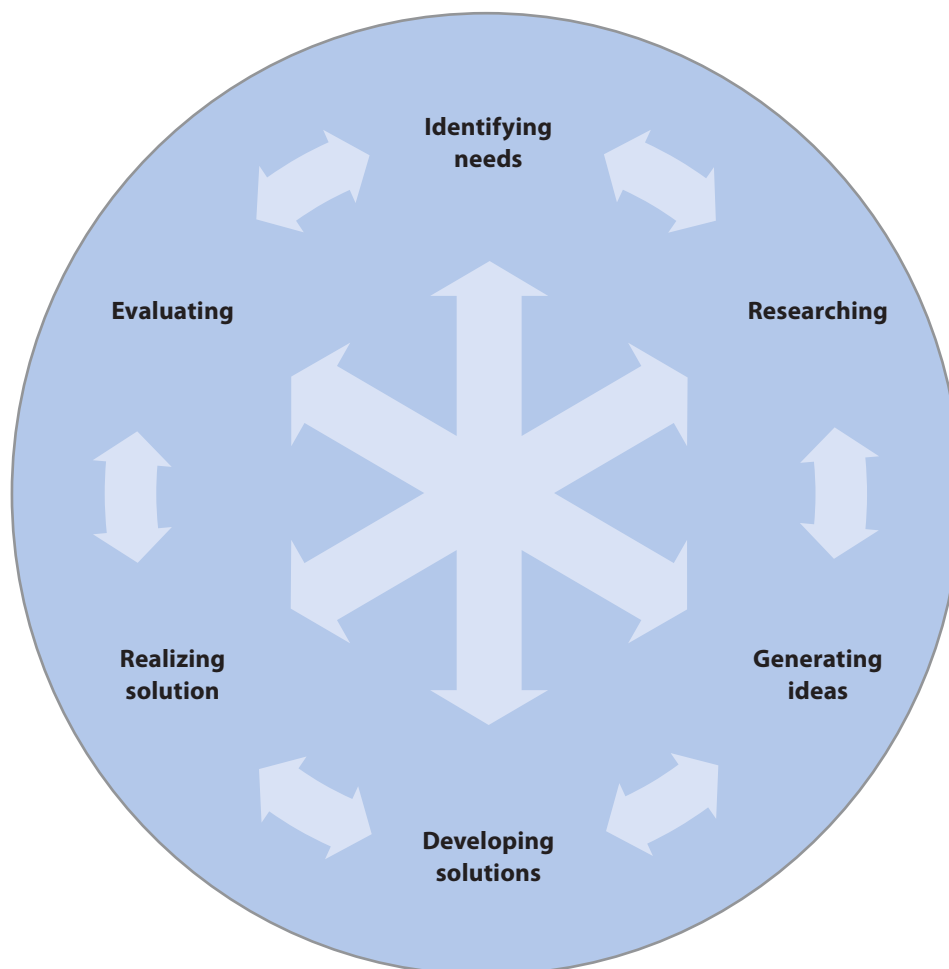
Topic 1: Design process (10 hours)

This topic introduces the design cycle model—a fundamental concept underpinning the design process and central to a student’s understanding of design activities. Each element of the design cycle represents how designers progress through the design process to refine the design solution in increasing detail. The topic then moves on to focus on the strategies that designers use to arrive at solutions to problems, and the varied nature of the skills and knowledge they need to carry out their activities successfully. The skills identified in this topic should be reflected in the internal assessment (IA) and reinforced throughout the course.

1.1 The design cycle model and the design process

3 hours

	Assessment statement	Obj	Teacher’s notes
1.1.1	Describe how designers use design cycle models to represent the design process.	2	Design may be described in a variety of ways and degrees of complexity. Some design cycle models are simple and some are more complex. The design process usually consists of successive stages that can be arranged as a systematic cyclical process that eventually converges to produce a solution to a problem.
1.1.2	List the stages in the IB design cycle model (DCM).	1	The DCM comprises six stages, as follows: <ul style="list-style-type: none"> • identifying or clarifying a need or opportunity • analysing, researching and specifying requirements • generating ideas and solutions • developing the chosen solution • realizing the chosen solution • testing and evaluating the chosen solution.



IB design cycle model

	Assessment statement	Obj	Teacher's notes
1.1.3	Describe a design brief.	2	<p>The design brief is the formal starting point for a new design. It is a statement of the expectations of the design. The brief does not provide the design solution, but is a statement that sets out:</p> <ul style="list-style-type: none"> the design goal (for example, a working prototype to be evaluated in terms of its feasibility for volume production) the target market for the product (for example, for children, disabled adults) the major constraints (for example, should comply with new legislation, have fewer working parts, be cheaper to manufacture) within which it must be achieved the criteria by which a good design proposal may be achieved (for example, increased value for money and/or cost-effectiveness for manufacturer).

	Assessment statement	Obj	Teacher's notes
1.1.4	Describe the identifying or clarifying a need or opportunity stage of the IB design cycle model.	2	The context of the problem is described and a concise brief stated. The design process can begin with a problem, an identified need, a market opportunity, a demand, a desire to add value to an existing product, or a response to opportunities presented by technological developments. The initial design problem is a loose collection of constraints, requirements and possibilities. From this, the designer has to make a coherent pattern. The design brief states the intended outcome and the major constraints within which it must be achieved.
1.1.5	Describe a design specification.	2	The design specification justifies the precise requirements of a design. The specification will include a full list of the criteria against which the specification can be evaluated.
1.1.6	Describe the analysing, researching and specifying requirements stage of the IB design cycle model.	2	Developing the specification from the brief is an evolving process beginning with an initial set of specifications and culminating in a final product design specification (PDS).
1.1.7	Describe the generating ideas and solutions stage of the IB design cycle model.	2	Divergent thinking is used to consider ways in which a problem may be solved. The starting point for the generation of ideas should be the design specification, and proposals should be evaluated against this specification, with evidence of relevant research used to rate the ideas in terms of their usefulness. A variety of approaches should be used, and different possibilities explored and analysed, before deciding on the most suitable solution.
1.1.8	Describe the developing the chosen solution stage of the IB design cycle model.	2	A final concept is developed taking into account the conflicting needs of the manufacturer and the user, and the requirement of the design as set out in the specifications. A complete proposal is developed based upon the research and the designer's personal ideas. This stage involves detailed drawings (of a style relevant to the task).
1.1.9	Describe the testing and evaluating the chosen solution stage of the IB design cycle model.	2	The final outcome is tested and evaluated against the requirements set out in the specification. Recommendations for modifications to the design are made. A reiteration process should now begin.
1.1.10	Explain why the IB design cycle model is not linear and why it is iterative in practice, thus making it representative of design thought and action.	3	The model emphasizes that designing is not a linear process. Evaluation, for example, will take place at various stages of the process, not just at the end. Similarly, ideas for possible solutions are not only generated at the "generating ideas" stage; some good ideas may develop even as early as the "identifying needs" stage. In practice, it is impossible to separate the stages of the design process as clearly as the model suggests.
1.1.11	Explain the role of the designer in the design process.	3	The designer's role varies depending on the complexity of the process and the intended outcome.

	Assessment statement	Obj	Teacher's notes
1.1.12	Describe how designers interact with others and how the emphasis of the design process varies depending on the designer's role.	2	Designers often work as members of a team. Priorities will vary depending on the nature of the activity. For example, the information required by an architect will be different from that required by an engineer.
1.1.13	Explain why elements of the model may differ in importance according to the particular design context.	3	Depending upon the nature of the problem, not all elements of the cycle carry the same weight in terms of time allocation and complexity. Points to consider include cost, resources, skills, time, original design specification and product modification.
1.1.14	Define <i>incremental design</i> , <i>radical design</i> , <i>convergent thinking</i> and <i>divergent thinking</i> .	1	
1.1.15	Describe the relationship between incremental design and convergent thinking.	2	
1.1.16	Describe the relationship between radical design and divergent thinking.	2	
1.1.17	Explain how elements of the design model reflect convergent and divergent thinking.	3	Convergent thinking is analytical and solution-focused, for example, during evaluation. Divergent thinking is conceptual and problem-focused, for example, used to generate ideas.
1.1.18	Explain how design work is often a combination of incremental and radical thinking.	3	For example, the use of a new material for a product may be a radical leap forwards but the product may look very similar to previous products: a tennis racquet made from carbon fibre is a radical development, but the shape and form are similar to previous designs.

1.2 Generating ideas

2 hours

	Assessment statement	Obj	Teacher's notes
1.2.1	Define <i>constructive discontent</i> .	1	
1.2.2	Identify a design context where constructive discontent has been the primary generator of ideas.	2	
1.2.3	Define <i>adaptation</i> .	1	
1.2.4	Identify a design context where adaptation has been the primary generator of ideas.	2	
1.2.5	Define <i>analogy</i> .	1	
1.2.6	Identify a design context where analogy has been the primary generator of ideas.	2	
1.2.7	Define <i>brainstorming</i> .	1	
1.2.8	Identify a design context where brainstorming has been the primary generator of ideas.	2	

	Assessment statement	Obj	Teacher's notes
1.2.9	Define <i>attribute listing</i> .	1	
1.2.10	Identify a design context where attribute listing has been the primary generator of ideas.	2	
1.2.11	Define <i>morphological synthesis</i> .	1	
1.2.12	Identify a design context where morphological synthesis has been the primary generator of ideas.	2	
1.2.13	Discuss why designers use a variety of techniques to develop ideas.	3	Actual techniques selected depend upon: personal choice, design context and time/resources available.

1.3 Communicating ideas

5 hours

	Assessment statement	Obj	Teacher's notes
1.3.1	Define <i>freehand drawing</i> .	1	
1.3.2	Describe the importance of annotating freehand drawings.	2	Annotations explain the thinking behind the visual image represented by the drawing. They allow the designer to consider the implications of the ideas for further development.
1.3.3	Explain the purpose of two- and three-dimensional (2D and 3D) freehand drawings.	3	Designers use a range of freehand drawings in the early stages of developing ideas to explore shape and form (3D) and constructional details (2D).
1.3.4	Define <i>orthographic drawing</i> .	1	
1.3.5	Explain the purpose of an orthographic drawing.	3	An orthographic drawing shows details and dimensions and can be used as a production drawing.
1.3.6	Identify the stage of the design process where orthographic drawings are relevant.	2	Orthographic drawings are produced at the final solution stage and are used as working drawings in the realization stage.
1.3.7	Define <i>isometric drawing</i> .	1	
1.3.8	Explain the purpose of an isometric drawing.	3	An isometric drawing depicts the proposed solution in 3D showing shape and form.
1.3.9	Define <i>exploded isometric drawing</i> .	1	
1.3.10	Explain the purpose of an exploded isometric drawing.	3	The drawing is exploded to show component parts of a product and/or the sequence of assembly.
1.3.11	Define <i>perspective drawing</i> .	1	
1.3.12	Explain the purpose of perspective drawing.	3	Compare perspective drawings with isometric drawings. Perspective drawings take into account spatial arrangements, for example, foreshortening, while isometric drawings are constructed to a set angle.
1.3.13	Define <i>computer-aided design (CAD)</i> and <i>computer modelling</i> .	1	

	Assessment statement	Obj	Teacher's notes
1.3.14	Outline two advantages and two disadvantages of using CAD instead of traditional drawing methods.	2	Consider the skills required, storage, complexity and styles of the drawings, interfacing with other aspects of information and communication technology (ICT), time, cost and the purpose of the drawings.
1.3.15	Define <i>algorithm</i> .	1	
1.3.16	Describe how an algorithm can be used to communicate a process.	2	For example, consider the operation of a lift. Correct sequencing is important, with input, process and feedback.
1.3.17	Define <i>flow chart</i> .	1	
1.3.18	Draw a simple flow chart using symbols.	1	
1.3.19	Describe how a flow chart can be used to communicate a process.	2	
1.3.20	Explain the differences between flow charts and algorithms.	3	
1.3.21	Describe models as representations of reality and representing selected features of a design.	2	
1.3.22	Describe a range of physical models.	2	Consider scale model, clay model and prototype. Refer to a range of modelling materials, for example, clay, card, foam, board, balsa and wood.
1.3.23	Explain the purpose of the various models described in 1.3.22.	3	
1.3.24	Define <i>mathematical model</i> .	1	
1.3.25	Describe the role of spreadsheet software in the development of mathematical models.	2	
1.3.26	Outline the advantages and disadvantages of graphical, physical and mathematical models.	2	
1.3.27	Describe three advantages of using models as part of the design process.	2	Communication with clients, communication with team members, and ability to manipulate ideas better than with drawings.
1.3.28	Describe three limitations of the use of models in the design process.	2	Designers can easily make assumptions about how accurately a model represents reality: it may not work like the final product or be made of the same material.

Topic 2: Product innovation (7 hours)

Innovation and the continuous development of new and improved products are key to the design process. This topic considers the relationship between the design cycle and the product cycle. It moves on to explore the role of invention in innovation and the impact of market pull and technology push on product innovation. Establishing and developing markets for products are a critical element of the product cycle.

2.1 Designers and the product cycle

2 hours

	Assessment statement	Obj	Teacher's notes
2.1.1	Describe the product cycle.	2	
2.1.2	Discuss the role of the designer in the product cycle.	3	Designing is part of the product cycle: as a need is generated, a product is designed, made and sold, eventually becoming obsolete. The cycle is complicated by distributors, retailers, accountants and production engineers, all of whom have an influence over the cycle. Although the designer is an integral part of the process, he or she is not necessarily in control (unlike in the design process). Computer-aided design (CAD) and computer-aided manufacture (CAM), where a prototype is produced by the designer from his or her personal computer (PC), blurs this distinction.
2.1.3	Outline the product cycle in terms of early, mature and late stages of development.	2	In the early stages of the product cycle, many changes to the product take place until it develops to the mature stage, where it is diffused into the market, gains acceptance and sells well. In the late stage, the product begins to decline in need and therefore in sales.
2.1.4	Identify products that are at the early, mature and late stages of their product cycle.	2	The ballpoint pen is in the mature stage, as it still sells well although the design does not change much. The cassette tape is in the late stage, as it has been overtaken by successive generations of products.
2.1.5	Compare the design cycle with the product cycle.	3	Highlight how the design process is aimed at producing a suitable solution to a problem, and that the product cycle is concerned with putting that solution into commercial practice.
2.1.6	Discuss why for many products the product cycle has shortened.	3	Compare a laptop computer and a ballpoint pen. Laptop computers are an intensely competitive market, with size and power being key issues.

2.2 Invention and innovation

3 hours

	Assessment statement	Obj	Teacher's notes
2.2.1	Define <i>invention</i> and <i>innovation</i> .	1	
2.2.2	Outline the stages of innovation.	2	Developing an idea into a viable product; its production; marketing and sales; followed by redesign; and the cycle or spiral continues.

	Assessment statement	Obj	Teacher's notes
2.2.3	Discuss the importance of science to invention and innovation.	3	Science explains how the world is.
2.2.4	Discuss the importance of technology to invention and innovation.	3	Technology uncovers new possibilities for materials, manufacturing techniques and processes.
2.2.5	Explain why the majority of inventions fail to become innovations.	3	Consider marketability, financial support, marketing, the need for the invention, price, resistance to change, and aversion to risk.
2.2.6	Explain the relevance of design to innovation.	3	For continued innovations (re-innovation), products and processes are constantly updated (redesigned) to make them more commercially viable and to give consumers choice and improved products.
2.2.7	Define <i>dominant design</i> , <i>diffusion into the marketplace</i> , <i>market pull</i> and <i>technology push</i> .	1	
2.2.8	Describe a design context where dominant design is relevant.	2	For example, ballpoint pen (Biro), Apple® iPod®, Coca-Cola®.
2.2.9	Explain the difficulties of getting a product to diffuse into the marketplace.	3	Consider local, national and global competition. The problems of getting novel products to market include product launches and marketing.
2.2.10	Explain why it is difficult to determine whether market pull or technology push is the impetus for the design of new products.	3	Push and pull are present in most successful innovations. The explanation should apply only to the origin of the idea or where the idea seems to have been generated.
2.2.11	Define <i>lone inventor</i> .	1	
2.2.12	Discuss why it is becoming increasingly difficult to be a successful lone inventor.	3	Most products are now extremely complex and rely on expertise from various disciplines. Most designs are developed by multidisciplinary teams.
2.2.13	Explain why lone inventors often find it difficult to work in the design departments of large companies.	3	They are often used to setting their own targets rather than working as members of teams. They can be dogmatic in their methodology and less flexible than team workers.
2.2.14	Define <i>product champion</i> .	1	
2.2.15	Compare the lone inventor with the product champion.	3	The lone inventor may lack the business acumen to push the invention through to innovation. The product champion is often a forceful personality with much influence in a company. He or she is more astute at being able to push the idea forward through the various business channels and is often able to consider the merits of the invention more objectively.
2.2.16	Explain why innovators may have difficulty in obtaining financial support for an invention.	3	Most people with money to invest will be inclined to wait until it is clearer whether an invention is going to be successful before investing: the problem is to get them to take the risk.

2.3 People and markets

2 hours

	Assessment statement	Obj	Teacher's notes
2.3.1	Define <i>technophile</i> , <i>technocautious</i> and <i>technophobe</i> .	1	
2.3.2	Explain how people can be broadly classified according to their reactions to technological change.	3	People's reactions to technological change vary depending on their values and personal circumstances. First-order effects and second-order effects should be taken into account, for example, personal gain in owning a car versus social and environmental considerations.
2.3.3	Define <i>corporate strategy</i> .	1	
2.3.4	Describe the corporate strategy referred to as "pioneering".	2	Pioneering means being ahead of the competitors by introducing a new product first. It is the most risky (costly) strategy but one with the potential for the largest gains. A pioneering company requires a strong research and development (R&D) capability, which is expensive. A pioneering company needs to be financially secure and requires product champions to push new ideas. Consider the Sony or Apple companies and their various pioneering developments. Good market research can offset some risk, but is problematic for novel products.
2.3.5	Describe the corporate strategy referred to as "imitative".	2	The imitative strategy aims to develop a product similar to the "pioneered" product as quickly as possible. It takes advantage of R&D invested by others, and is less risky, but is based on a strong development capability.
2.3.6	Explain the benefits for a company of using a hybrid strategy.	3	
2.3.7	Define <i>market penetration</i> .	1	
2.3.8	Describe a strategy that a company would use to enhance market penetration.	2	Consider product promotion through marketing.
2.3.9	Define <i>market development</i> .	1	
2.3.10	Describe how a company would undertake market development.	2	The identification of new markets for products, for example, nylon was originally developed for parachutes.
2.3.11	Define <i>product development</i> .	1	
2.3.12	Describe one example of how a company undertakes product development.	2	Consider adding variations to a product to develop a range of products building on an established brand, for example, ice cream, snack food products, chocolate products (Kit Kat, Mars bars).
2.3.13	Define <i>diversification</i> .	1	
2.3.14	Describe one example of diversification.	2	For example, a company manufacturing three-pin electrical plugs may consider producing them in a range of colours or from materials of different textures and/or material properties.
2.3.15	Define <i>market sector</i> and <i>market segmentation</i> .	1	

	Assessment statement	Obj	Teacher's notes
2.3.16	Outline two ways in which markets may be segmented.	2	Consider income, age, lifestyle, geographical location, and so on.
2.3.17	Define <i>robust design</i> and <i>product family</i> .	1	
2.3.18	Discuss an example of a robust design that evolved into a product family.	3	

Topic 3: Green design (9 hours)

Green design involves taking a “cradle to grave” approach to the design of a product by considering the adverse impacts of the product at all stages of its life (pre-production, production, distribution, including packaging, utilization and disposal) and seeking to minimize those impacts.

3.1 Principles of green design

2 hours

	Assessment statement	Obj	Teacher's notes
3.1.1	Define <i>green design</i> , <i>renewable resources</i> and <i>non-renewable resources</i> .	1	
3.1.2	Outline the reasons for green design.	2	Consider consumer pressure and legislation.
3.1.3	List design objectives for green products.	1	Objectives include: <ul style="list-style-type: none"> • increasing efficiency in the use of materials, energy and other resources • minimizing damage or pollution from the chosen materials • reducing to a minimum any long-term harm caused by use of the product • ensuring that the planned life of the product is most appropriate in environmental terms and that the product functions efficiently for its full life • taking full account of the effects of the end disposal of the product • ensuring that the packaging and instructions encourage efficient and environmentally friendly use • minimizing nuisances such as noise or smell • analysing and minimizing potential safety hazards.
3.1.4	Discuss the impact of “take back” legislation on designers and manufacturers of cars, refrigerators and washing machines.	3	

	Assessment statement	Obj	Teacher's notes
3.1.5	Explain how people can be broadly classified according to their attitudes to green issues.	3	People's attitudes to green issues vary. Eco-warriors actively demonstrate on environmental issues. Eco-champions champion environmental issues within organizations. Eco-fans enthusiastically adopt environmentally friendly practices as consumers. Eco-phobes actively resent talk of environmental protection.

3.2 Life cycle analysis

5 hours

	Assessment statement	Obj	Teacher's notes
3.2.1	Define <i>life cycle analysis</i> .	1	
3.2.2	Describe how life cycle analysis provides a framework within which clean production technologies and green design can be evaluated holistically for a specific product.	2	
3.2.3	List the key stages in life cycle analysis.	1	Pre-production, production, distribution including packaging, utilization and disposal.
3.2.4	List the major environmental considerations in life cycle analysis.	1	Water, soil pollution and degradation, air contamination, noise, energy consumption, consumption of natural resources, pollution and effect on ecosystems.
3.2.5	Describe how the life cycle stages and the environmental considerations can be organized into an environmental impact assessment matrix.	2	
3.2.6	Analyse the environmental impact of refrigerators, washing machines and cars using an environmental impact assessment matrix.	3	
3.2.7	Explain why elements of the matrix may differ in importance according to the particular design context.	3	
3.2.8	Identify the roles and responsibilities of the designer, manufacturer and user at each life cycle stage of a product.	2	
3.2.9	Describe one example of a situation where life cycle analysis identifies conflicts that have to be resolved through prioritization.	2	
3.2.10	Explain that life cycle analysis is targeted at particular product categories.	3	Life cycle analysis is targeted at products with a high environmental impact and in the global marketplace. It is then impossible for companies to argue that their products are being made uncompetitive. Life cycle analysis also targets companies with the resources to invest in R&D.

	Assessment statement	Obj	Teacher's notes
3.2.11	Explain why life cycle analysis is not widely used in practice.	3	Life cycle analysis is not used for many products. However, in the re-innovation of the design of a product or its manufacture, specific aspects may be changed after considering the design objectives for green products. Thus the materials selected may be changed to make them more environmentally friendly, for example, wood from sustainable forests or the selection of a less toxic varnish. A product may be distributed differently or its packaging may be redesigned.
3.2.12	Describe the reasons for the introduction of eco-labelling schemes.	2	
3.2.13	Explain how eco-labelling reflects life cycle analysis of certain product categories.	3	
3.2.14	Compare the objectives of two different eco-labelling schemes.	3	Consider approaches to eco-labelling in Europe, Australia and the United States (US).
3.2.15	Explain how eco-labelling and energy-labelling schemes can help consumers to compare potential purchases.	3	

3.3 Strategies for green design

2 hours

	Assessment statement	Obj	Teacher's notes
3.3.1	Define <i>design for manufacture</i> (DfM).	1	
3.3.2	Describe why DfM can be a dominating constraint on the design brief and state that it can be conveniently split into design for materials, design for process and design for assembly.	2	
3.3.3	Define <i>design for materials</i> , <i>design for process</i> and <i>design for assembly</i> .	1	
3.3.4	Discuss three strategies that designers could employ for DfM.	3	Strategies include: minimizing the number of components, using standard components, designing components that are multifunctional or for multi-use, designing parts for ease of fabrication, minimizing handling, and using standard sub-assemblies.
3.3.5	Describe how designers can modify the environmental impact of the production, use and disposal of their product through careful consideration at the design stage.	2	
3.3.6	Define <i>reuse</i> , <i>repair</i> , <i>reconditioning</i> and <i>recycling</i> .	1	

	Assessment statement	Obj	Teacher's notes
3.3.7	Describe how reuse, repair, reconditioning and recycling contribute to the optimization of resource utilization.	2	
3.3.8	Describe how the strategies of reuse, repair and recycling can be applied to the design of products, including packaging.	2	For example, consider disposable cameras, vacuum cleaners and car tyres.
3.3.9	List three material groups that can be easily and economically recycled.	1	Consider thermoplastics, metals and glass.
3.3.10	Describe how many products comprise several different materials, and state that these materials have to be separated to enable recycling.	2	
3.3.11	Discuss the issues underpinning the economic recycling of materials.	3	Consider collection, energy and processing considerations, redistribution.
3.3.12	Define <i>design for disassembly</i> .	1	
3.3.13	Explain that design for disassembly is one aspect of design for materials and will facilitate recycling of products on disposal.	3	
3.3.14	Discuss two strategies that designers could employ to design for disassembly.	3	Designing components made from one material. Using thermoplastic adhesives that lose their properties when reheated. Designing snap fittings instead of welding and glueing.

Topic 4: Materials (17 hours)

4.1 Introducing and classifying materials

1 hour

	Assessment statement	Obj	Teacher's notes
4.1.1	Define <i>atom</i> , <i>molecule</i> , <i>alloy</i> and <i>composite</i> .	1	
4.1.2	Describe a bond as a force of attraction between atoms.	2	Consider and differentiate between the three main types of bond: ionic, covalent and metallic.
4.1.3	Describe how materials are classified into groups according to similarities in their microstructures and properties.	2	
4.1.4	Explain that several classifications are recognized but that no single classification is "perfect".	3	It is convenient to be able to classify materials into categories (albeit crude in nature) that have characteristic combinations of properties.

	Assessment statement	Obj	Teacher's notes
4.1.5	Describe that, for this course, materials are classified into groups: timber, metals, plastics, ceramics, food and composites; and that some of these groups have subdivisions.	2	In each group there can be subdivisions, for example, for timber (natural wood and man-made), metals (ferrous and non-ferrous), plastics (thermoplastics, thermosets), ceramics (earthenware, porcelain, stoneware, glass), textile fibres (natural or synthetic), food (vegetable or animal origin) and composites (difficult to classify due to variability and continual development of new composite materials). Food is included here for completeness, although it is dealt with in detail as an option.

4.2 Properties of materials

3 hours

	Assessment statement	Obj	Teacher's notes
Physical properties			
4.2.1	Define <i>density</i> , <i>electrical resistivity</i> , <i>thermal conductivity</i> , <i>thermal expansion</i> and <i>hardness</i> .	1	
4.2.2	Explain a design context where each of the properties in 4.2.1 is an important consideration.	3	<p>Density is important in relation to product weight and size (for example, for portability). Pre-packaged food is sold by weight or volume, and a particular consistency is required.</p> <p>Electrical resistivity is particularly important in selecting materials as conductors or insulators.</p> <p>Thermal conductivity is important for objects that will be heated or must conduct or insulate against heat.</p> <p>Thermal expansion (expansivity) is important where two dissimilar materials are joined. These may then experience large temperature changes while staying joined.</p> <p>Hardness is important where resistance to penetration or scratching is required. Ceramic floor tiles are extremely hard and resistant to scratching.</p>
Mechanical properties			
4.2.3	Define <i>tensile strength</i> , <i>stiffness</i> , <i>toughness</i> and <i>ductility</i> .	1	
4.2.4	Explain a design context where each of the properties in 4.2.3 is an important consideration.	3	<p>Tensile strength is important in selecting materials for ropes and cables, for example, for an elevator.</p> <p>Stiffness is important when maintaining shape is crucial to performance, for example, an aircraft wing.</p> <p>Toughness is important where abrasion and cutting may take place.</p> <p>Ductility is important when metals are extruded (not to be confused with malleability, the ability to be shaped plastically).</p>

	Assessment statement	Obj	Teacher's notes
Aesthetic characteristics			
4.2.5	Outline the characteristics of taste, smell, appearance, texture and colour.	2	
4.2.6	Explain a design context where each of the characteristics in 4.2.5 is an important consideration.	3	Some of these properties are only relevant to food, while others can be applied to more than one material group. Although these properties activate people's senses, responses to them vary from one individual to another, and they are difficult to quantify scientifically, unlike the other properties.

4.3 Timber

3 hours

	Assessment statement	Obj	Teacher's notes
4.3.1	Describe the structure of natural timber.	2	Natural timber is a natural composite material comprising cellulose fibres in a lignin matrix. The tensile strength of timber is greater along the grain (fibre) than across the grain (matrix).
4.3.2	Outline that timber can be classified according to the conditions needed for tree growth.	2	Consider temperate and tropical conditions. A general knowledge of the geographical distribution of world timber resources is required.
4.3.3	Outline that conifer trees are referred to as softwoods and that these grow only in temperate regions.	2	Recognize the characteristics of softwood trees.
4.3.4	Outline that deciduous trees are referred to as hardwoods and that these grow in both temperate and tropical regions.	2	Recognize the characteristics of hardwood trees.
4.3.5	Discuss the issues relating to the consideration of timber as a renewable resource.	3	Consider time to reach maturity, soil erosion, greenhouse effect and extinction of species. The issues should be placed in local, national and international contexts.
4.3.6	List two examples of composite timbers.	1	Consider particle board (chipboard) and plywood.
4.3.7	Compare the characteristics of particle board, laminated woods (for example, plywood), pine wood (a softwood) and mahogany (a hardwood).	3	Consider composition, hardness, tensile strength, resistance to damp environments, longevity and the aesthetic properties of grain, colour and texture. The ability to produce sketches showing cross-sectional views of the structure of the materials is expected.
4.3.8	Outline criteria for the selection of timber for different structural and aesthetic design contexts.	2	Consider timber for buildings, furniture and children's toys.
4.3.9	Describe the reasons for treating or finishing wood.	2	Consider reducing attack by organisms and chemicals, enhancing aesthetic properties and modifying other properties.
4.3.10	Explain three differences in the selection of timbers for flooring if it were made of a hardwood, a softwood or a composite material.	3	Consider durability, ease of maintenance and aesthetics.

4.4 Metals

3 hours

	Assessment statement	Obj	Teacher's notes
4.4.1	Draw and describe a metallic bond.	2	Metals are often described as positively charged nuclei in a sea of electrons. The outer electrons of the metal atom nuclei are free and can flow through the crystalline structure. The bonding is caused by attraction between the positively charged metallic atom nuclei and the negatively charged cloud of free electrons. Specific arrangements of metal atoms are not required.
4.4.2	Explain how the movement of free electrons makes metals very good electrical and thermal conductors.	3	
4.4.3	State that metals (pure or alloyed) exist as crystals.	1	Crystals are regular arrangements of particles (atoms, ions or molecules). Details of types of crystals are not required.
4.4.4	Draw and describe what is meant by grain size.	2	
4.4.5	Explain how grain size can be controlled and modified by the rate of cooling of the molten metal, or by heat treatment after solidification.	3	Reheating a solid metal or alloy allows material to diffuse between neighbouring grains and the grain structure to change. Slow cooling allows larger grains to form; rapid cooling produces smaller grains. Directional properties in the structure may be achieved by selectively cooling one area of the solid.
4.4.6	Define <i>plastic deformation</i> .	1	
4.4.7	Explain how metals work-harden after being plastically deformed.	3	
4.4.8	Describe how the tensile strength of a metal is increased by alloying.	2	
4.4.9	Explain the effect of alloying on malleability and ductility.	3	The presence of "foreign" atoms in the crystalline structure of the metal interferes with the movement of atoms in the structure during plastic deformation.
4.4.10	Describe a superalloy.	2	The strength of most metals decreases as the temperature is increased. Superalloys are metallic alloys that can be used at high temperatures, often in excess of 0.7 of their absolute melting temperature.
4.4.11	List two design criteria for superalloys.	1	Consider creep and oxidation resistance.
4.4.12	Identify applications for superalloys.	2	Superalloys can be based on iron, cobalt or nickel. Nickel-based superalloys are particularly resistant to temperature and are appropriate materials for use in aircraft engines and other applications that require high performance at high temperatures, for example, rocket engines, chemical plants.

4.5 Plastics

3 hours

	Assessment statement	Obj	Teacher's notes
4.5.1	Describe a covalent bond.	2	In a covalent bond the outer electrons of some atoms come close enough to overlap and are shared between the nuclei, forming a covalent bond. Each pair of electrons is called a covalent bond. Mention of sigma (σ), pi (π), double or triple bonds is not required. Covalent bonds are strong bonds and examples of primary bonds (as are metallic and ionic bonds).
4.5.2	Describe secondary bonds as weak forces of attraction between molecules.	2	
4.5.3	Describe the structure and bonding of a thermoplastic.	2	Thermoplastics are linear chain molecules with weak secondary bonds between the chains.
4.5.4	Describe the effect of load on a thermoplastic with reference to orientation of the polymer chains.	2	Deformation occurs in two ways: <ul style="list-style-type: none"> • elastic, in which initially coiled chains are stretched and the material returns to its original size and shape when the load is removed • plastic, when at higher loads the secondary bonds between the chains weaken and allow the molecular chains to slide over each other, and the material does not return to its original size and shape when the load is removed. Creep and flow are important. No quantitative details are required.
4.5.5	Explain the reversible effect of temperature on a thermoplastic, with reference to orientation of the polymer chains.	3	Increase in temperature causes plastic deformation.
4.5.6	Explain how the reversible effect of temperature on a thermoplastic contributes to the ease of recycling of thermoplastics.	3	
4.5.7	Draw and describe the structure and bonding of a thermoset.	2	Thermosets are linear chain molecules with strong primary bonds between adjacent polymer chains. This gives thermosets a rigid 3D structure.
4.5.8	Explain the non-reversible effect of temperature on a thermoset.	3	
4.5.9	Discuss the properties and uses of polypropene and polyethene thermoplastic materials.	3	
4.5.10	Discuss the properties and uses of polyurethane and urea–formaldehyde (methanal) thermoset materials.	3	
4.5.11	Discuss the issues associated with the disposal of plastics, for example, polyvinyl chloride (PVC).	3	Although PVC disposal is problematic, PVC is still widely used as a structural material, for example, in windows and for guttering and drainpipes.

4.6 Ceramics

2 hours

	Assessment statement	Obj	Teacher's notes
4.6.1	Describe the composition of glass.	2	Glass is composed primarily of silicon dioxide together with some sodium oxide and calcium oxide and small quantities of a few other chemicals.
4.6.2	Explain that glass is produced from sand, limestone and sodium carbonate, and requires large quantities of energy for its manufacture.	3	Scrap glass is added to new raw materials to make the process more economical.
4.6.3	Describe the characteristics of glass.	2	Consider brittleness, transparency, hardness, unreactivity and aesthetic properties.
4.6.4	Explain that the desired characteristics of glass can be accurately determined by altering its composition.	3	Consider soda glass and Pyrex®.
4.6.5	Outline the differences between toughened and laminated glass.	2	Consider their responses to being flexed and to impact.
4.6.6	Explain why glass is increasingly used as a structural material.	3	Consider the use of plate glass and glass bricks as wall and flooring materials. Consider material properties, for example, resistance to tensile and compressive forces, thermal conductivity and transparency. Consider aesthetic properties and psychological benefits: allows natural light into buildings and can visually link spaces, creating more interesting interiors.

4.7 Composites

2 hours

	Assessment statement	Obj	Teacher's notes
4.7.1	Describe composites.	2	Composites are a combination of two or more materials that are bonded together to improve their mechanical, physical, chemical or electrical properties.
4.7.2	Define <i>fibre</i> .	1	
4.7.3	Describe the matrix composition of composites.	2	
4.7.4	Explain that new materials can be designed by enhancing the properties of traditional materials to develop new properties in the composite material.	3	
4.7.5	Describe a smart material.	2	Smart materials have one or more properties that can be dramatically altered, for example, viscosity, volume, conductivity. The property that can be altered influences the application of the smart material.

	Assessment statement	Obj	Teacher's notes
4.7.6	Identify a range of smart materials.	2	Smart materials include piezoelectric materials, magneto-rheostatic materials, electro-rheostatic materials, and shape memory alloys. Some everyday items are already incorporating smart materials (coffee pots, cars, the International Space Station, eye-glasses), and the number of applications for them is growing steadily.
4.7.7	Describe a piezoelectric material.	2	When a piezoelectric material is deformed, it gives off a small electrical discharge. When an electric current is passed through it, it increases in size (up to a 4% change in volume). They are widely used as sensors in different environments. Specific details of crystalline structure are not required.
4.7.8	Outline one application of piezoelectric materials.	2	Piezoelectric materials can be used to measure the force of an impact, for example, in the airbag sensor on a car. The material senses the force of an impact on the car and sends an electric charge to activate the airbag.
4.7.9	Describe electro-rheostatic and magneto-rheostatic materials.	2	Electro-rheostatic (ER) and magneto-rheostatic (MR) materials are fluids that can undergo dramatic changes in their viscosity. They can change from a thick fluid to a solid in a fraction of a second when exposed to a magnetic (for MR materials) or electric (for ER materials) field, and the effect is reversed when the field is removed.
4.7.10	Outline one application of electro-rheostatic materials and one application of magneto-rheostatic materials.	2	MR fluids are being developed for use in car shock absorbers, damping washing machine vibration, prosthetic limbs, exercise equipment, and surface polishing of machine parts. ER fluids have mainly been developed for use in clutches and valves, as well as engine mounts designed to reduce noise and vibration in vehicles.
4.7.11	Describe shape memory alloys (SMAs).	2	SMAs are metals that exhibit pseudo-elasticity and shape memory effect due to rearrangement of the molecules in the material. Pseudo-elasticity occurs without a change in temperature. The load on the SMA causes molecular rearrangement, which reverses when the load is decreased and the material springs back to its original shape. The shape memory effect allows severe deformation of a material, which can then be returned to its original shape by heating it.
4.7.12	Identify applications of SMAs.	2	Applications for pseudo-elasticity include eye-glasses frames, medical tools and antennas for mobile phones. One application of shape memory effect is for robotic limbs (hands, arms and legs). It is difficult to replicate even simple movements of the human body, for example, the gripping force required to handle different objects (eggs, pens, tools). SMAs are strong and compact and can be used to create smooth lifelike movements. Computer control of timing and size of an electric current running through the SMA can control the movement of an artificial joint. Other design challenges for artificial joints include development of computer software to control artificial muscle systems, being able to create large enough movements and replicating the speed and accuracy of human reflexes.

Topic 5: Product development (11 hours)

5.1 Manufacturing techniques

1.5 hours

	Assessment statement	Obj	Teacher's notes
5.1.1	Define <i>manufacturing technique</i> .	1	
5.1.2	Outline the techniques of moulding, casting, weaving, fusing, stitching, cutting, machining, abrading, using adhesives and using fasteners.	2	The principles of each technique are required.
5.1.3	Describe how the techniques in 5.1.2 relate to different materials.	2	For example, casting relates to metals, plastics, food, ceramics and some composites, but not to timber or textiles.
5.1.4	Discuss advantages and disadvantages of using the techniques to manufacture products.	3	Refer to the viewpoints of the manufacturer and the user.

5.2 Craft production

1.5 hours

	Assessment statement	Obj	Teacher's notes
5.2.1	Define <i>craft production</i> and <i>one-off production</i> .	1	
5.2.2	Describe why most products were manufactured by craft techniques prior to the Industrial Revolution.	2	Refer to the development of skills; sources of materials and energy; sales and distribution; relationship of craftsman or designer with client or consumer.
5.2.3	Explain the advantages and disadvantages of craft production.	3	Consider economies of scale, value of the product, labour, market forces and flexibility of manufacture.
5.2.4	Discuss the importance of craft production for developed and developing countries.	3	Economic development, infrastructure and market needs should be considered, but also the rise of the "master craftsman" in industrialized countries.

5.3 Mechanization

2 hours

	Assessment statement	Obj	Teacher's notes
5.3.1	Define <i>mechanization</i> .	1	
5.3.2	Describe how the availability of new sources of power in the Industrial Revolution led to the introduction of mechanization.	2	Refer to water and steam power.
5.3.3	Define <i>assembly-line production</i> .	1	
5.3.4	Explain the relevance of assembly-line production to mechanization.	3	Refer to economics, design of products, effect on the workforce and consumer choice.
5.3.5	Outline two advantages and two disadvantages of mechanizing a production process.	2	Consider cost, quality of product, social conditions and labour.

	Assessment statement	Obj	Teacher's notes
5.3.6	Define <i>batch production</i> and <i>mass production</i> .	1	
5.3.7	Compare batch production and mass production in a mechanized production system.	3	Consider market needs, consumer choice, product differentiation and economies of scale.

5.4 Automation

2 hours

	Assessment statement	Obj	Teacher's notes
5.4.1	Define <i>automation</i> .	1	
5.4.2	Describe how the development of computer and information technology in the “technological revolution” led to the introduction of automation.	2	Refer also to the importance of electricity.
5.4.3	Define <i>computer-aided manufacture</i> (CAM) and <i>computer numerical control</i> (CNC).	1	
5.4.4	Explain how CAD, CAM and CNC contribute to an automated production system.	3	Consider the wide variety of systems available.
5.4.5	Define <i>just-in-time</i> (JIT) and <i>just-in-case</i> (JIC).	1	
5.4.6	Explain the advantages of JIT and JIC to manufacturing.	3	Refer to reliability, efficiency, distribution, workforce, storage, capital investment, stock control and traditions.
5.4.7	Define <i>mass customization</i> .	1	
5.4.8	Outline how mass customization is changing the relationship between the manufacturer and the consumer.	2	The relationship is akin to craft production, where the individual requirements of the consumer dominate.
5.4.9	Discuss the impact of automation on working conditions.	3	Consider nature and type of employment, health and safety issues, social interaction and job satisfaction.
5.4.10	Outline how automation has improved the type and range of products available to consumers.	2	Many products require such precision in their manufacture that, without automation, it would not be possible to produce them at an affordable price.

5.5 Economic considerations

2 hours

	Assessment statement	Obj	Teacher's notes
5.5.1	List the costs that contribute to the final cost of a product.	1	Take into account scale of production, complexity of product, resources, skills, quality control, size and weight of product for storage and distribution, type of advertising and marketing, profits and taxes. Include costs relating to availability and procurement of materials, R&D, labour, manufacturing costs, capital costs, overheads, distribution and sales.

	Assessment statement	Obj	Teacher's notes
5.5.2	Define <i>fixed costs</i> and <i>variable costs</i> .	1	
5.5.3	Identify the factors in 5.5.1 as fixed costs or variable costs.	2	
5.5.4	Explain how the costs in 5.5.1 relate to craft production, mechanization and automation.	3	For example, raw materials and labour costs will be significant for an individually crafted mahogany table, but for an injection-moulded plastic component these costs would be low and the capital cost of machinery high.
5.5.5	Explain the concept of “break-even point” in relation to fixed and variable costs.	3	Once “break-even” point is reached, profits can be made, because fixed costs have been covered. Variable costs will continue to rise with increased production.

5.6 Clean manufacturing

2 hours

	Assessment statement	Obj	Teacher's notes
5.6.1	Explain why the introduction of mass production increased damage to the natural environment.	3	A historical perspective is important. Environmental considerations were not an issue in the 18th and 19th centuries. Little quantitative data was available, and all governments encouraged the growth of industry.
5.6.2	Outline the reasons for cleaning up manufacturing.	2	Reasons include promoting positive impacts, ensuring neutral impact or minimizing negative impacts through conserving natural resources, reducing pollution and use of energy, and reducing wastage of energy and resources.
5.6.3	Outline that an initial response to reducing emission of pollutants is adding clean-up technologies to the end of the manufacturing process.	2	The addition of clean-up technologies to the end of the manufacturing process is termed the “end-of-pipe” approach.
5.6.4	Explain how legislation provides an impetus to manufacturers to clean up manufacturing processes.	3	
5.6.5	State that the legislation can be policed by monitoring through the collection of quantitative data.	1	
5.6.6	Explain that strategies for cleaning up manufacturing are mainly reactive, and that more radical approaches require a rethink of the whole system and may result in significant product and/or process modification or radically new technologies.	3	Many companies react to legislation or impending legislation by doing the minimum required. More radical approaches, for example, life cycle analysis, are proactive (see “Topic 3: Green design”).
5.6.7	Explain that targets for reducing pollution and waste from industry are agreed internationally, but not all industrial nations agree to the targets.	3	Explore the difficulties of stating targets against the background of ever-changing social, political and economic changes.

Topic 6: Product design (5 hours)

6.1 Ergonomics

2 hours

	Assessment statement	Obj	Teacher's notes
6.1.1	Define <i>ergonomics</i> , <i>anthropometrics</i> and <i>percentile range</i> .	1	
6.1.2	State that ergonomics is multidisciplinary, encompassing anthropometrics, psychological factors and physiological factors.	1	
6.1.3	Describe a design context where the 5th–95th percentile range has been used.	2	For example, mass-produced clothing.
6.1.4	Describe a design context where the 50th percentile has been used.	2	For example, height of a desk.
6.1.5	Explain the limitations of using the 50th percentile as a means of designing for the “average” person.	3	The 50th percentile refers to one particular dimension. For example, someone may be average in height but not average in other dimensions.
6.1.6	Identify specific design contexts where the designer would use percentile ranges for particular user groups.	2	For example, toys for young children.
6.1.7	Outline the significance of psychological factors (smell, light, sound, taste, texture and temperature) to ergonomics.	2	Individuals react differently to sensory stimuli. Efficiency and comfort are affected by such factors.
6.1.8	Outline physiological factors that affect ergonomics.	2	For example, bodily tolerances such as fatigue and comfort.
6.1.9	Discuss the influence of perception when collecting data relating to psychological factors.	3	Quantitative data may be used in a design context relating to psychological factors, but individuals vary in their reaction to the data. For example, one person will find a room temperature comfortable while another person will find it uncomfortable, though the temperature is constant.

6.2 The designer and society

3 hours

	Assessment statement	Obj	Teacher's notes
6.2.1	Discuss moral and social responsibilities of designers in relation to green design issues.	3	Consider issues relating to waste, pollution, resources, market forces and wealth creation.
6.2.2	Define <i>planned obsolescence</i> .	1	
6.2.3	Outline how planned obsolescence influences the design specification of a product.	2	Consider materials and construction, durability and ease of maintenance.

	Assessment statement	Obj	Teacher's notes
6.2.4	Describe the advantages and disadvantages of planned obsolescence to the designer, manufacturer and consumer.	2	Refer to consumer choice, value, R&D and product life cycle.
6.2.5	Define <i>fashion</i> .	1	
6.2.6	Compare the influence of fashion and planned obsolescence on the product cycle.	3	Planned obsolescence has a definite timescale; fashion is less predictable. Both may be present. For example, a certain colour may be fashionable for a car but this does not affect materials or technological obsolescence.
6.2.7	Evaluate the influence of fashion and planned obsolescence in relation to the quality and value of a product.	3	Consider whether “designer” products are better quality than cheaper brands of the same product, and also question the values of a “throw-away society”.
6.2.8	Explain how aesthetic considerations affect the design of products.	3	Refer to shape and form, texture and colour.
6.2.9	Discuss the conflict that a designer faces when attempting to balance form with function in the design of products.	3	Examples should be used, for example, a car or domestic products.

Topic 7: Evaluation (6 hours)

7.1 Evaluation and designing

2 hours

	Assessment statement	Obj	Teacher's notes
7.1.1	Outline the general criteria used to evaluate products.	2	Consider performance, reliability, ease of use, safety, aesthetics, materials, construction and cost.
7.1.2	Explain how the criteria used to evaluate products will vary depending on the purpose of the evaluation.	3	For example, crash-testing cars is done in relation to safety only.
7.1.3	Apply the general criteria to evaluate products.	2	
7.1.4	Explain the use of qualitative and/or quantitative tests, models and experiments used to evaluate ideas at the design development stage (developing chosen solution) of the design cycle.	3	Consider the use of scale models to evaluate shape, form and proportion; materials tests; construction technique tests, and so on.
7.1.5	Define <i>literature search</i> .	1	
7.1.6	Describe one advantage and one disadvantage of literature search for data collection.	2	Many sources of information are available, but there may be an abundance of data, which can be too time-consuming.
7.1.7	Evaluate the importance of ICT in aiding literature searching.	3	Consider access to information, speed, costs, storage and security.

	Assessment statement	Obj	Teacher's notes
7.1.8	Define <i>user trial</i> .	1	
7.1.9	Describe one advantage and one disadvantage of a user trial to collect data.	2	The “user” is a non-specialist, which makes trials easier and cost-effective. However, users may carry out tasks in different ways from those expected and be inexperienced.
7.1.10	Define <i>user research</i> .	1	
7.1.11	Describe one advantage and one disadvantage of user research to collect data.	2	Data is relatively easy and cheap to obtain but is largely qualitative.
7.1.12	Compare user research with user trial.	3	With user research, data is collected by obtaining users' responses to questions. User trial data is collected by observing users' behaviour.
7.1.13	Define <i>expert appraisal</i> .	1	
7.1.14	Describe one advantage and one disadvantage of using expert appraisal to collect data.	2	For example, expert knowledge and advice are gained (compared to a user trial), but the expert may be biased. It may also be difficult to locate an expert. Data is usually qualitative.

7.2 Evaluation and manufacturing

2 hours

	Assessment statement	Obj	Teacher's notes
7.2.1	Identify the nature of evaluation at different stages of the product cycle.	2	Different types of market research, for example, evaluating competitive products, evaluating the success of a new product and evaluating for redesign.
7.2.2	Define <i>cost-effectiveness</i> .	1	
7.2.3	Explain the importance of cost-effectiveness to manufacturers.	3	In order to maximize profit, manufacturers require the most cost-effective production system. This is often the major aim of the brief for designers.
7.2.4	Define <i>quality control</i> and <i>quality assurance</i> .	1	
7.2.5	Compare quality control with quality assurance for manufactured products.	3	
7.2.6	Define <i>performance test</i> .	1	
7.2.7	Describe one advantage and one disadvantage of using a performance test to collect data.	2	It is possible to collect quantitative data, but the test may be time-consuming and costly. It can be used where a user trial is not feasible, for example, crash-testing cars.
7.2.8	Define <i>field trial</i> .	1	
7.2.9	Describe one advantage and one disadvantage of using a field trial to collect data.	2	Field trials are usually quite extensive exercises, so can be expensive, but the product is tested in the marketplace, which provides data that is different from laboratory-based evaluations.

7.3 Evaluation and the consumer

2 hours

	Assessment statement	Obj	Teacher's notes
7.3.1	Define <i>value for money</i> .	1	
7.3.2	Compare price with value when assessing a product for value for money.	3	If the price is too high, there may not be enough potential purchasers who can afford it or think the product is value for money. If the price is too low, consumers may think the product is too cheap to have much value. Demand for a product will generally establish the maximum price that can be charged, and the costs of production will determine the minimum price that is acceptable. However, a company may choose to set its price in relation to its competitors, or it may choose to set the price in accordance with the perceived value of the product.
7.3.3	Explain how consumers apply criteria to evaluate a product for value for money, referring to before purchase, purchase, initial use and long-term use.	3	Before purchase: advertising, manufacturer's specification, list price, product image, and evaluation by experts and consumer groups. Purchase: aesthetics, performance, build quality and purchase price. Initial use: actual performance, safety and ease of use. Long-term use: reliability, ease of maintenance, durability and running costs.
7.3.4	Discuss how the criteria in 7.3.3 are assigned different weightings depending on the design context.	3	Value judgments play a part in product analysis, and they vary according to the individual, the time (era) and the circumstances. Consumers often value utility, security, availability, rarity and aesthetics, while designers may consider function, reliability and ease of maintenance more important.
7.3.5	Explain the relevance of quality assurance to consumers.	3	Quality assurance means that consumers do not have to carry out their own research when considering purchasing products, and they have a means of redress if a product fails to match expected standards, for example, via a guarantee.
7.3.6	Discuss the role of consumer associations for product evaluation.	3	Consumer associations are independent organizations. They carry out tests on products to see if manufacturers' claims are justified, and they provide published data for consumers. They compare similar products within a target market and recommend the best value-for-money products.
7.3.7	Explain the contribution of the media and education to product evaluation.	3	Consider the contribution of consumer and lifestyle programmes, the weekend sections of newspapers and consumer journals, and their focus on new products. Also curriculum development and design education in schools.

Syllabus details—AHL

Topic 8: Energy (9 hours)

8.1 Historical overview

3 hours

	Assessment statement	Obj	Teacher's notes
8.1.1	Outline two types of energy.	2	Energy is classified as kinetic and potential energy. Kinetic energy is the energy associated with a moving object, for example, a moving football, a speeding train, a waterfall or a rock falling from a cliff. Potential energy is the energy in an object due to its position or the arrangement of its parts. It includes gravitational, elastic, chemical and electromagnetic potential energy. Gravitational potential energy is produced when an object is lifted up and work is done against the force of gravity. As the object falls, potential energy is converted to kinetic energy. Elastic potential energy is produced when an object (such as a spring or a rubber band) resists being stretched out of shape. The energy from the deformation of the band can be converted into kinetic energy and used to do work, for example, to spin a propeller or power a toy airplane. Chemical potential energy is the energy that holds molecules together. Combustion, for example, of fossil fuels, releases the energy, which can be used to do work. Electromagnetic potential energy can be stored in a battery or supplied from a power plant, hydroelectric dam or windmill. Thermal energy is the movement of molecules that make up the object. All objects possess thermal energy (even cold ones), since they have a temperature above absolute zero.
8.1.2	Describe how human muscle power was the only source of energy for (craft) production until the Industrial Revolution.	2	
8.1.3	Describe how development of machines based on flowing water led to a revolution in production.	2	The water wheel enabled the harnessing of energy for production. However, the water wheel had a fixed location next to a fast-flowing river and so lacked flexibility.
8.1.4	Describe how the invention of the steam engine and the use of steam as the basis for the operation of machines led to a large increase in scale of production based on coal.	2	Steam power is more efficient than water power, but still only 30% of the energy produced is converted. The advantage of steam power is that it is more movable and therefore flexible. Consider the impact of the steam engine on the mechanization of the cotton industry.

	Assessment statement	Obj	Teacher's notes
8.1.5	Explain how the development of electricity led to a technological revolution and an increased volume of production.	3	Faraday's discovery of electromagnetic induction and the invention of the dynamo allowed the energy from coal or fast-flowing water to be converted into electricity. As a result, the electricity industry was established, with a sophisticated infrastructure enabling a new generation of electrical machines and electrical products. Factory production and the development of assembly-line arrangements enabled the development of a vast range of cheaper products.
8.1.6	Identify uses for the electric motor in industrial production.	2	Consider the application of rotary motion in drills, saws, lathes and belt systems.
8.1.7	Explain how the production and distribution of electricity led to large-scale energy usage, security of supply and the geographical spread of production away from the source of energy supplies.	3	The electrical distribution network and grid system allowed industry to move away from the source of the fuel supply.
8.1.8	Explain how the development of localized, portable sources of electrical energy in the form of batteries changed the nature of energy usage and the development of new types of products.	3	Consider portable radios, mobile phones, and other portable electrical and electronic products.

8.2 Types of energy: economic, environmental and political aspects

3 hours

	Assessment statement	Obj	Teacher's notes
8.2.1	List the main forms of non-renewable energy sources.	1	Consider coal, oil, timber and gas.
8.2.2	Discuss the efficiency of conversion of fossil fuels into electrical energy.	3	See also teacher's notes in 8.1.1. Fossil fuel burning is an extremely inefficient method of energy conversion. Coal is least efficient (about 30%), then oil (about 35%) and gas (about 40%). Waste energy is dissipated into the atmosphere or water (lake, sea or river).
8.2.3	Outline how modern industrial societies have become dependent on non-renewable fossil fuels as the major sources of energy supply and electricity production.	2	There are cheap and plentiful supplies for electricity production and other energy needs. However, the depletion of supplies of coal, oil and gas challenges continuity of supply in the longer term.
8.2.4	Outline the main pollutants produced from the large-scale burning of fossil fuels worldwide.	2	Sulphur emissions cause acid rain; CO ₂ , although not strictly a pollutant, contributes to the enhanced greenhouse effect.
8.2.5	Describe the main effect of carbon dioxide emissions from the large-scale burning of fossil fuels.	2	Enhanced greenhouse effect leads to higher mean global temperatures, sea-level rise and general climate changes.

	Assessment statement	Obj	Teacher's notes
8.2.6	Discuss the use of technologies to make energy conversion from fossil fuels more efficient and cleaner.	3	Consider clean coal technology.
8.2.7	Discuss two approaches to reducing the enhanced greenhouse effect based on international agreements to reduce emissions of CO ₂ and the promotion of clean technologies.	3	Consider the Kyoto Protocol, which uses economic mechanisms, and the Asia-Pacific Partnership on Clean Development and Climate (APPCDC), which looks at technology solutions.
8.2.8	List the main forms of renewable energy sources.	1	Consider wind, solar, tidal, wave, hydroelectric and biomass.
8.2.9	Explain why there is increasing pressure to use renewable energy sources.	3	Consider higher cost of oil, political instability, security of supply, greenhouse effect leading to climate change, and other pollution.
8.2.10	Discuss the limitations of the use of renewable energy resources as alternatives for fossil fuels.	3	Limitations include high cost, unreliable supply and low energy density.
8.2.11	Discuss the advantages and disadvantages of nuclear power.	3	Very low CO ₂ emissions, high energy density versus safety issues, high cost of decommissioning, possible radioactive contamination, waste product storage problems, and link with nuclear weapons.
8.2.12	Discuss the role of energy conservation in energy policy.	3	Reduced usage by sustainable development policies, for example, sustainable transport systems and building systems (see also "Topic 12: Sustainable development").
8.2.13	Outline new sources of energy.	2	Consider biofuels.
8.2.14	Discuss the contribution of biomass as a renewable energy resource.	3	Can replace petrol in the internal combustion engine and be used as a biomass fuel.

8.3 Case studies

3 hours

	Assessment statement	Obj	Teacher's notes
Solar power			
8.3.1	Describe how solar power can be harnessed for use in domestic products.	2	Consider active solar collection and various arrangements of photovoltaic cells (PVs), for example, small individual cells on portable equipment, use of PVs in sustainable building design for hybrid systems, incorporation of PVs into roof design to enhance the sustainability of buildings and also doubling as shelter over car parking areas.
8.3.2	Identify the advantages and disadvantages of solar power.	2	Consider set-up costs, running costs and maintenance, and continuity of supply.
8.3.3	Describe the design of a solar cooker.	2	

	Assessment statement	Obj	Teacher's notes
8.3.4	Discuss the importance of solar cooking in sustainable development.	3	In some rural areas, for example, Nepal, traditional cooking methods involve the burning of biomass fuels and result in indoor air pollution, which is one of the four most critical environmental problems in developing countries. Women and children are more likely to be exposed to indoor air pollution as many women in developing countries spend hours per day cooking near an open fire often with a child strapped to their backs. Indoor air pollution can damage lungs, contributing to acute lower respiratory infections, chronic lung disease, lung cancer, asthma, low birth weight and heart disease. Collection of wood and other biomass fuels contributes to deforestation, with impacts on the water table.
Energy and transport			
8.3.5	Compare individual and mass transport systems for sustainable development.	3	
8.3.6	Discuss the barriers to transition from individual cars to mass public transport systems.	3	Consider convenience, flexibility, systems integration, for example, park-and-ride systems.
Wind energy			
8.3.7	Identify the advantages and disadvantages of small-scale and large-scale wind energy generating plants.	2	Consider small-scale wind energy generating systems, for example, for isolated houses, and large-scale wind energy generating systems for communities and feeding into the national grid.
8.3.8	Discuss the issues associated with the siting of large wind farms.	3	Consider impacts on the environment; noise and visual pollution; community lobbying and "not in my back yard" (NIMBY); who pays for the developments; onshore and offshore developments.

Topic 9: Structures (10 hours)

9.1 Young's modulus—stress and strain

2 hours

	Assessment statement	Obj	Teacher's notes
9.1.1	Define <i>Young's modulus</i> .	1	
9.1.2	State that stress (load) is force per unit area acting on a body or system.	1	
9.1.3	State that strain is the ratio of a change in dimension to the original value of that dimension.	1	

	Assessment statement	Obj	Teacher's notes
9.1.4	Draw and describe a stress/strain graph and identify the elastic region, plastic flow region, yield stress and ultimate tensile strength (UTS).	2	For most materials the elastic region is a straight line, which changes to a curved line (plastic region). Quantitative details of specific materials are not required.
9.1.5	Outline the importance of yield stress in materials.	2	This is the stress at the yield point on the stress/strain graph. Beyond the yield point, the material undergoes plastic deformation.
9.1.6	Explain the difference between plastic and elastic strains.	3	When a material behaves elastically, if the stress on the material is released before it breaks, the extension (strain) relaxes and the material returns to its original length. Beyond the yield point, the material deforms plastically and does not return to its original length or shape.
9.1.7	Calculate the Young's modulus of a range of materials.	2	Young's modulus = $\frac{\text{stress}}{\text{strain}}$
9.1.8	Explain how knowledge of the Young's modulus of a material affects the selection of materials for particular design contexts.	3	Young's modulus provides quantitative data relating to the relationship of strength and stiffness in structures.

9.2 Forces

2 hours

	Assessment statement	Obj	Teacher's notes
9.2.1	Describe what is meant by an external load acting on a structure.	2	This involves loads where physical contact is made.
9.2.2	Describe what is meant by body load.	2	This is a load without physical contact, for example, a structure's own weight.
9.2.3	Describe the difference between weight and mass.	2	Refer to the effect of gravity and how commonly people refer to the weight of an object when they should refer to its mass.
9.2.4	State the units of weight and mass.	1	
9.2.5	Explain the relationship of external loads to internal forces and the concept of the balance of equilibrium of forces within a structure.	3	
9.2.6	Explain how a structure "works" by interpreting how external loads give rise to internal forces within the structural members.	3	A static structure is in equilibrium, otherwise it would move (the forces acting upon it are equal in size and opposite in direction).
9.2.7	Explain the differences between tensile and compressive forces and how they affect equilibrium within a structure.	3	Tensile loads tend to extend or stretch a structural member. Compressive loads tend to compress or shorten a structural member. Tensile and compressive forces must balance if the structure is to maintain equilibrium. Only forces that are parallel or perpendicular need to be considered. Knowledge of trigonometry or quantitative resolution of vectors into components is not required.

	Assessment statement	Obj	Teacher's notes
9.2.8	Calculate a tensile or compressive stress, given values of force and area.	2	$\text{Stress} = \frac{\text{force}}{\text{area}}$
9.2.9	Calculate a tensile or compressive strain, given values of the original dimension and the change in dimension.	2	$\text{Strain} = \frac{\text{change of length}}{\text{original length}}$
9.2.10	Evaluate the importance of forces in a design context.	3	

9.3 The strength and stiffness of structures

3 hours

	Assessment statement	Obj	Teacher's notes
9.3.1	Explain the relationship between deflection and stiffness in structures.	3	If an external load is applied to some part of a structure, that part will be deflected to an extent that depends on the size of the load and the stiffness of the structure.
9.3.2	Calculate the stiffness of a structure.	2	$\text{Stiffness} = \frac{\text{load}}{\text{deflection}}$
9.3.3	Outline what is meant by bending moment in relation to structures.	2	This is the moment that a beam has to resist in bending at a particular section.
9.3.4	Outline what is meant by moment arm.	2	The load \times distance from the pivot is called the moment about the pivot. The distance between the load and the pivot is called the moment arm.
9.3.5	Explain the need for a factor of safety in structural design.	3	Structures are designed to take higher loads than those they are normally expected to support.
9.3.6	Calculate the factor of safety for a structure.	2	$\text{Factor of safety} = \frac{\text{design load}}{\text{normal maximum load}}$
9.3.7	Apply the concept of factor of safety to other areas of design.	2	A factor of safety is simply the ratio of the quantitative value of a design (factor) divided by the normal maximum expected value.
9.3.8	Evaluate the importance of strength and stiffness in a design context.	3	

9.4 Beams

3 hours

	Assessment statement	Obj	Teacher's notes
9.4.1	Describe a beam.	2	Beams are structural members that are subject to loads acting normally to their longitudinal axis. The loads create shear stresses and bending moments and cause the beam to bend or flex. Beams are classified according to the way they are supported; for example, cantilever beams are rigidly supported at one end with the other end free.

	Assessment statement	Obj	Teacher's notes
9.4.2	Describe how beams are designed to transfer forces and distribute loads through the beams.	2	
9.4.3	Describe the historical development of the materials used to manufacture beams.	2	Solid wood beams—high bulk. Concrete beams with metal. Metal sectional beams. Reduction in the amount of material in the beam.
9.4.4	Identify a variety of shapes for sectional members of a structure.	2	Consider rectangular, circular, L-shaped, I-shaped, castle-shaped.
9.4.5	Describe how the shape of sectional members of a structure makes the most effective and economic use of materials.	2	
9.4.6	Explain that sectional members of a structure may be manufactured in sheet material.	3	For example, laminated veneer lumbar (LVL).
9.4.7	Outline the benefits of using LVL beams in the construction industry.	2	LVL is used in place of more expensive wooden beams where the finished product is hidden by other forms of cladding.
9.4.8	Explain the importance of factor of safety in the design of beams.	3	

Topic 10: Mechanical design (8 hours)

10.1 General concepts

4 hours

	Assessment statement	Obj	Teacher's notes
10.1.1	Define <i>mechanical advantage</i> , <i>velocity ratio</i> and <i>efficiency</i> .	1	
10.1.2	Calculate mechanical advantage (MA), velocity ratio (VR) and efficiency for simple mechanical systems.	2	$MA = \frac{\text{load}}{\text{effort}}$ $VR = \frac{\text{distance moved by effort}}{\text{distance moved by load}}$ $\text{Efficiency} = \frac{MA}{VR}$
Levers			
10.1.3	Describe first-, second- and third-class levers.	2	Identify load (L), effort (E) and fulcrum (F) in first-class levers (E–F–L, for example, seesaw, crowbar, scissors), second-class levers (E–L–F, for example, wheelbarrow, bottle opener, nutcracker) and third-class levers (L–E–F, for example, tweezers, broom, fishing rod).
10.1.4	Discuss the relevant efficiencies of the three classes of lever.	3	

	Assessment statement	Obj	Teacher's notes
10.1.5	Explain that, when a lever is in equilibrium, the net moment is zero.	3	
10.1.6	Calculate mechanical advantage and effort for first-, second- and third-class levers.	2	
Gears			
10.1.7	Describe gear systems.	2	
10.1.8	Calculate velocity ratio for gear systems.	2	
10.1.9	Describe the function of different types of gears in a range of objects.	2	Use rack-and-pinion, bevel and worm gears.
10.1.10	Explain a design context in which a compound rather than a simple gear train would be appropriate.	3	Consider the gearing system on a metal lathe designed to be changed to cut a specific type of thread. Consider ratios, mechanical advantage and changes.
10.1.11	Discuss the function of different types of gears in a range of objects.	3	Use rack-and-pinion, bevel and worm gears.
Belts			
10.1.12	Describe a belt or chain drive system.	2	Consider profile, load, changes in load, and speed.
10.1.13	Calculate velocity ratio for belt or chain drive systems.	2	
10.1.14	Compare belt or chain drives and gear systems.	3	Consider profile, load, changes in load, and speed.
10.1.15	Design a system to provide belt torsion to a belt-and-pulley system.	3	
Pulleys			
10.1.16	Describe a pulley system.	2	
10.1.17	Calculate mechanical advantage for pulley systems.	2	
Inclined plane			
10.1.18	Describe an inclined plane.	2	Consider inclined planes, screw threads and wedges.
10.1.19	Explain the advantage of an inclined plane.	3	

10.2 Mechanical motion

2 hours

	Assessment statement	Obj	Teacher's notes
10.2.1	Describe linear, rotary, intermittent, oscillating, reciprocating and irregular motion.	2	
10.2.2	Explain how linkages can be used to change the direction of motion of components.	3	
10.2.3	Discuss mechanical motion in a range of contexts.	3	Consider a hydraulic digger, a bicycle, a car jack and a hand drill.
10.2.4	Define <i>torque</i> .	1	
10.2.5	Discuss the design features of a ratchet and pawl system.	3	
10.2.6	Describe simple cam shapes and their advantages.	2	
10.2.7	Identify cam followers and state their use.	2	
10.2.8	Explain the use of a series of cam and follower mechanisms to achieve a set purpose.	3	This can be explored in a number of ways: using Lego, paper and pins, or through virtual online models.

10.3 Conversion of motion

2 hours

	Assessment statement	Obj	Teacher's notes
10.3.1	Identify how mechanisms allow conversion of one form of motion to another.	2	For example, rack and pinion, bell cranks, toggle clamps, linkages and levers.
10.3.2	Identify the mechanisms in a bicycle.	2	Consider chain drive, levers, linkages and gears.
10.3.3	Design combinations of mechanisms to achieve specific tasks.	3	Consider the following tasks: <ul style="list-style-type: none"> • alter the axis of rotation • change the type of movement • increase force and decrease speed • decrease force and increase speed.
10.3.4	Discuss how designers make use of simple mechanisms in the home.	3	Consider water tap, garlic crusher and foot-operated trash/rubbish bin.

Topic 11: Advanced manufacturing techniques (10 hours)

11.1 Joining

2 hours

	Assessment statement	Obj	Teacher's notes
11.1.1	Describe friction welding.	2	Friction welding is a completely mechanical solid-phase process in which heat generated by friction is used to create the ideal conditions for a high-integrity welded joint between similar or dissimilar metals.
11.1.2	Explain how two metal parts are welded using friction.	3	Diagrams should include two parts, one revolving, and the other fixed.
11.1.3	Describe plastic welding.	2	Consider hot air and friction welding techniques.
11.1.4	Explain how two plastic parts are welded together.	3	Only thermoplastics that do not burn or decompose when heated to their softening temperature can be welded.
11.1.5	Define <i>permanent joining techniques</i> .	1	
11.1.6	List a range of permanent joining techniques.	1	Consider pop-rivets, brazing, welding and adhesives.
11.1.7	Discuss how permanent joining techniques lead to planned obsolescence and environmental issues.	3	Permanent joins do not allow for the disassembly and easy maintenance of products.
11.1.8	Define <i>adhesive</i> .	1	
11.1.9	Identify a range of adhesives suitable for joining metals, woods and plastics.	2	PVA (polyvinyl acetate), epoxy resin, contact adhesive, cascamate, tensol cement and superglue (cyanoacrylate).
11.1.10	Discuss the advantages and disadvantages of using adhesive bonding in products.	3	Consider preparation of surfaces, clamping, bonding time, type of material, and health and safety.

11.2 Moulding

3 hours

	Assessment statement	Obj	Teacher's notes
11.2.1	Define <i>sprue, flash, parison, die, draft angle</i> and <i>injection moulding</i> .	1	
11.2.2	Explain how an injection-moulded product is made.	3	Diagrams must include the hopper, hydraulics, heaters, screw, sprue and mould.
11.2.3	Outline the advantages of injection moulding.	2	Consider initial capital investment, tooling, accuracy, quality control and quantity of product.

	Assessment statement	Obj	Teacher's notes
11.2.4	Discuss how standardized bottle caps have constrained bottle design, but have cut costs for manufacturers.	3	Bottle caps can be classed as standardized parts. Bottle tops are injection moulded, while bottles are normally made by blow moulding. It is financially beneficial for a blow moulding company to use off-the-shelf bottle tops instead of purchasing an injection moulding machine and new tooling.
11.2.5	Describe how a blow-moulded product is made.	2	Diagrams must include the extruder, parison, the mould and air inlet.
11.2.6	Explain how a rotational-moulded product is made.	3	Diagrams must include the mould, filling the mould, heater chamber, rotation and cooling chamber.
11.2.7	Explain how a compression-moulded product is made.	3	Diagrams must include the mould, pre-form, hydraulic press, finished part and flash material.
11.2.8	Discuss why some products have to be made using compression moulding.	3	Consider the heat the product must withstand, quantity and type of product to be made. Refer to thermosets.
11.2.9	Describe how a vacuum-formed product is made.	2	Diagrams must include the vacuum chamber, former, platen, heater, air in and out.
11.2.10	Identify manufacturing methods suitable for thermoplastics and thermosets.	2	Thermoplastics: vacuum forming, blow moulding, injection moulding and rotational moulding. Thermosetting plastic: compression moulding.

11.3 Casting

3 hours

	Assessment statement	Obj	Teacher's notes
11.3.1	Describe lost wax casting.	2	
11.3.2	Describe how lost wax cast products are made.	2	Consider preparation of the master pattern; injection of wax to create copy; creation of a wax tree to make a wide range of small parts from the same metal; covering wax with ceramic or plaster of Paris; removal of wax; and the addition of the final chosen material.
11.3.3	Explain how a range of products are made using lost wax casting.	3	Jewellery, dental implants, hip replacements and wind instrument keys.
11.3.4	Describe high-pressure die casting.	2	Die casting is mainly used for low-melting alloys. Molten metal is forced into a mould under high pressure.
11.3.5	Describe how high-pressure die cast products are made.	2	Draw a diagram to include holding furnace, injector, gooseneck and die.
11.3.6	Explain how a range of products are made using high-pressure die casting.	3	Consider hip replacements, disk drive chassis and carburettors.
11.3.7	Outline two advantages and two disadvantages of high-pressure die casting.	2	Advantages: high accuracy, good surface finish, thin walls, and high rate of production. Disadvantages: high plant costs, high tooling costs, cannot be used for a wide range of alloys, and limitations on maximum size that can be cast.

11.4 Forming

2 hours

	Assessment statement	Obj	Teacher's notes
11.4.1	Describe the process of spray-up.	2	Spray-up is carried out on an open mould, where both the resin and reinforcements are sprayed directly onto the mould. The resin and glass may be applied separately or simultaneously "chopped" in a combined stream from a chopper gun. Workers roll out the spray-up to compact the laminate. Wood, foam or other core material may then be added, and a secondary spray-up layer embeds the core between the laminates (sandwich construction). The part is then cured, cooled and removed from the reusable mould.
11.4.2	Identify products that could be made using spray-up processes.	2	For example, pleasure boats and swimming pools.
11.4.3	Describe the process of hand lay-up.	2	In hand lay-up processing, fibreglass continuous strand mat and/or other fabrics such as woven roving are manually placed in the mould. Each ply is sprayed with catalysed resin and the resin is worked into the fibre with brushes and rollers to wet-out and compact the laminate.
11.4.4	Identify products that could be made using hand lay-up processes.	2	Products of varying sizes that do not need a high accuracy finish, for example, prototypes.
11.4.5	Describe the process of filament winding.	2	This process is primarily used for hollow, generally circular or oval-sectioned, components, such as pipes and tanks. Fibre tows are passed through a resin bath before being wound on to a mandrel in a variety of orientations, controlled by the fibre feeding mechanism, and rate of rotation of the mandrel. Filament winding machine design varies with part geometry.
11.4.6	Identify products that could be made using filament winding processes.	2	For example, fishing rods and rowing oars.
11.4.7	Describe the process of vacuum bagging.	2	This process is basically an extension of the wet lay-up process where pressure is applied to the laminate once laid-up in order to improve its consolidation. This is achieved by sealing a plastic film over the wet laid-up laminate and onto the tool. The air under the bag is extracted by a vacuum pump, and thus up to one atmosphere of pressure can be applied to the laminate to consolidate it.
11.4.8	Outline the benefits of using vacuum bagging when using composite lay-up techniques.	2	Large products are possible; top-quality products through the use of pre-pregs; clean production method; and low moulding costs.
11.4.9	Identify products that can be made using vacuum bagging processes.	2	For example, laminated curved furniture.

	Assessment statement	Obj	Teacher's notes
11.4.10	Explain how a curved shape is produced in timber using lamination.	3	Thin layers of ply or veneers are laid onto a former, then glued and clamped. To eliminate spring-back on tight curves, a fast drying adhesive should be used. Thicker timber can be steamed and shaped over a former. Some spring-back is likely to occur, but it is possible to reduce this by combining lamination and steaming.
11.4.11	Discuss how lamination can be used to strengthen material.	3	The structure of a timber is such that all fibres run along its length. Laminating more than one timber together but with fibres running at right angles increases the strength in all directions.
11.4.12	Describe how LVL differs from plywood.	2	Consider material cross-section and grain direction.
11.4.13	Discuss how forming techniques have enabled designers to be more flexible in the way they approach the design process.	3	Material choice, environment and cost factors can be more widely addressed.

Topic 12: Sustainable development (12 hours)

12.1 Appropriate technology and sustainable development

4 hours

	Assessment statement	Obj	Teacher's notes
12.1.1	Define <i>appropriate technology</i> , <i>sustainable development</i> and <i>triple bottom line sustainability</i> .	1	
12.1.2	List four characteristics of an appropriate technology.	1	
12.1.3	Describe one example of an appropriate technology.	2	For example, solar cooking, hybrid vehicles, wind-up torches.
12.1.4	Identify the three key dimensions of triple bottom line sustainability.	2	Economic sustainability: growth, development, productivity, trickle-down. Environmental sustainability: ecosystem integrity, carrying capacity, biodiversity. Social sustainability: cultural identity, empowerment, accessibility, stability, equity.
12.1.5	Explain how global conferences (for example, Rio de Janeiro, Johannesburg) provide a platform for the development of global strategies for sustainable development.	3	
12.1.6	Explain the ongoing challenges facing the achievement of a consensus on a strategy for sustainable development.	3	
12.1.7	Outline the Bellagio principles.	2	See "The Sustainability Report" of the International Institute for Sustainable Development.

	Assessment statement	Obj	Teacher's notes
12.1.8	Explain how progress towards sustainable development might be assessed using the Bellagio principles.	3	In 1996 the International Institute for Sustainable Development developed general guidelines for the practical assessment of progress towards sustainable development—the Bellagio principles. These identify common patterns in sustainable development-related assessments.
12.1.9	Explain why sustainable development requires systems-level changes in industry and society.	3	
12.1.10	Explain how sustainable development requires close cooperation between manufacturers and government.	3	
12.1.11	Explain how a close relationship between manufacturers and government can be difficult to achieve because the two parties may have very different perspectives on sustainability and timescales.	3	
12.1.12	Outline three reasons why it is difficult for governments to introduce legislation to cover all aspects of sustainability.	2	

12.2 Sustainable building design

8 hours

	Assessment statement	Obj	Teacher's notes
12.2.1	Define <i>intelligent building</i> , <i>living building</i> , <i>grey water</i> , <i>black water</i> , <i>building envelope</i> , <i>U value</i> , <i>passive solar design</i> , <i>daylighting</i> and <i>active solar collection</i> .	1	
12.2.2	List five objectives for sustainable buildings.	1	Objectives for sustainable buildings: <ul style="list-style-type: none"> • resource efficiency • energy efficiency • pollution prevention (including indoor air quality and noise abatement) • harmonization with the environment (including environmental assessment) • integrated and systemic approaches (including environmental management systems).
12.2.3	Explain the benefits of intelligent buildings to sustainable building design.	3	Effective energy management system, for example, provides lowest cost energy, avoids waste of energy by managing occupied space, and makes efficient use of staff through centralized control and integrating information from different sources.

	Assessment statement	Obj	Teacher's notes
12.2.4	Outline the key features of living buildings.	2	Harvest their own water and energy needs on site. Adapted specifically to site and climate and evolve as conditions change. Operate pollution-free and generate no waste that is not useful for some other process in the building or the immediate environment. Promote the health and well-being of all inhabitants. Comprise integrated systems that maximize efficiency and comfort. Improve the health and diversity of the local ecosystem rather than degrade it.
12.2.5	Identify ways in which water consumption in buildings can be optimized through reduction of water consumption and recycling.	2	Toilets (low flush, cistern displacement, waterless (composting, incinerating)), urinals (controls, waterless), wash-hand basins (push taps, flow controls), showers (water-saving shower heads or systems), water control in gardens and outside spaces, water-saving washing machines, water supply (auto shut-off and pressure regulators), rain water and grey water recycling systems.
12.2.6	Identify ways in which material use can be optimized through the life cycle of a building.	2	Manufacture: waste reduction, pollution prevention, use of recycled materials, embodied energy reduction (the quantity of energy required with all the activities associated with the production process, for example, energy to quarry, transport and manufacture building materials plus energy used in construction), natural materials. Operation: energy efficiency, water treatment and conservation, non-toxic, renewable energy resources, longer life. Disposal: biodegradable, recyclable, reusable.
12.2.7	Identify waste management strategies appropriate for sustainable buildings.	2	Waste prevention, recycling construction and demolition materials, architectural reuse (adaptive reuse, conservative disassembly, reuse of salvaged materials). Design for material recovery.
12.2.8	Identify ways in which the indoor environment of buildings can be optimized.	2	Indoor air quality, visual quality, acoustic quality, noise control, system controllability.
12.2.9	Explain how the building envelope contributes to the amount of energy a building uses during its operation.	3	Building envelope design is a major factor in determining the amount of energy a building will use in its operation. The building envelope must balance requirements for ventilation and daylight while providing thermal and moisture protection appropriate to prevailing climate.
12.2.10	Identify the key considerations to take into account when selecting materials for the building envelope.	2	Consider climate and activities inside the building.
12.2.11	Explain how the selection of different construction materials with different <i>U</i> values can contribute to heat loss or gain from a building.	3	Building materials conduct heat at different rates. Components of the envelope such as foundation walls, sills, studs, joists and connectors can create paths for the transfer of thermal energy.
12.2.12	Identify four factors that determine the heat flow through a material.	2	Area, thickness, temperature difference and thermal conductivity.

	Assessment statement	Obj	Teacher's notes
12.2.13	Calculate heat loss or gain through a building envelope comprising different materials.	2	Heat flow = wall area × temperature difference × <i>U</i> value
12.2.14	Explain how passive solar design can contribute to passive solar heating and/or cooling and reduce energy consumption in buildings.	3	When sunlight strikes a building, the building materials can reflect, transmit or absorb the solar radiation. Heat from the Sun causes air movement that can be predictable in designed spaces. Thus design elements, material choices and location can provide heating and cooling effects in a building.
12.2.15	Identify three ways in which passive solar design can be achieved.	2	Appropriate solar orientation (for example, elongate the east–west axis of the building, interior spaces requiring the most light and heating and/or cooling should face the Sun, less used spaces should be away from the Sun); use of thermal mass; appropriate ventilation and window placement; roof overhangs.
12.2.16	Explain how landscaping can contribute to reductions in energy consumption for buildings.	3	Careful landscape planning can reduce cooling and/or heating costs by 30%. Trees, grass and shrubs will also reduce air temperatures near the building and provide evaporative cooling. Trees provide shade, reduce the surface temperature of buildings and prevent direct heat gain through windows. Deciduous trees can provide shade in summer and admit light in winter when the leaves fall. Evergreen trees provide year-round Sun and wind protection. Windbreaks can reduce wind within a distance of three times their height.
12.2.17	Explain how daylighting can contribute to reductions in energy consumption for buildings.	3	Daylighting significantly reduces energy consumption and operating costs. Energy used for lighting in buildings can account for 40–50% of total energy consumption. The cooling required to counter waste heat generated by lights can amount to 3–5% of total energy use. Daylighting reduces the need for electrical light sources, cutting down on electricity use and its associated costs and pollution.
12.2.18	Explain how active solar collection can contribute to reductions in energy consumption for buildings.	3	Active solar collector systems take advantage of the Sun to provide energy for domestic water heating, pool heating, ventilation air pre-heat, and space heating. Water heating for domestic use is generally the most economical application of active solar systems. The demand for hot water is fairly constant throughout the year, so the solar system provides energy savings year-round. Major components of a system include collectors, a circulation system that moves the fluid between the collectors and storage, the storage tank, a control system, and a back-up heating system.

Syllabus details—Options SL and HL

SL students study the core of one of these options and HL students study the whole option (the core and the extension material).

Option A: Food science and technology (30/45 hours)

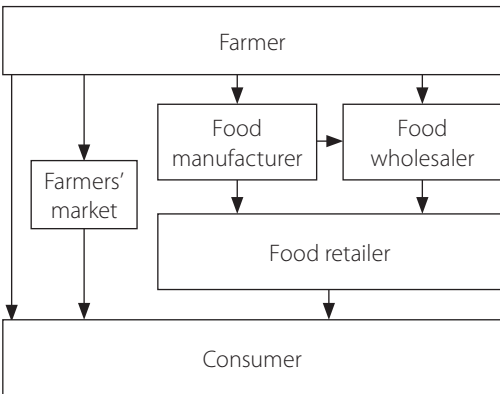
Core material: A1–A9 are core material for SL and HL (30 hours).

Extension material: A10–A12 are extension material for HL only (15 hours).

A1 Development of the food industry

4 hours

	Assessment statement	Obj	Teacher's notes
A.1.1	Explain that food is a precious, highly seasonal and perishable commodity that has to be handled carefully and in an appropriate and timely manner to ensure that it is safe to eat.	3	
A.1.2	Explain that food is a basic requirement for life and that humans need to eat at fairly frequent and regular intervals to survive.	3	
A.1.3	Describe how, before the Industrial Revolution, most people lived in rural areas and would have grown their own food.	2	
A.1.4	Explain how the food industry has developed in response to urbanization.	3	Following the Industrial Revolution, there was an increasing trend towards urbanization with most people not growing their own food but relying on other people (farmers) from whom they purchased foods either directly or indirectly.

	Assessment statement	Obj	Teacher's notes
A.1.5	Outline the roles of key stakeholders in the food chain between farmer and consumer.	2	 <pre> graph TD Farmer[Farmer] --> FarmersMarket[Farmers' market] Farmer --> FoodManufacturer[Food manufacturer] Farmer --> FoodWholesaler[Food wholesaler] FarmersMarket --> Consumer[Consumer] FoodManufacturer --> FoodWholesaler FoodManufacturer --> FoodRetailer[Food retailer] FoodWholesaler --> FoodRetailer FoodRetailer --> Consumer </pre> <p>Consider farmer, farmers' market, food manufacturer, food wholesaler, food retailer and consumer.</p>
A.1.6	Describe the role of primary processing and secondary processing in the production of food products.	2	Primary processing is the conversion of a crop into a product that may or may not be consumed directly. Primary processing is undertaken to enhance the shelf life, for example, flour, or ease of distribution of a product, for example, concentration of orange juice. Secondary processing is the conversion of an intermediate product into a final product for consumption, for example, flour to bread.
A.1.7	Outline three factors that determine a need for primary and/or secondary processing.	2	Consider storage properties, volume, weight and energy considerations.
A.1.8	Identify the key phases in the evolution of food outlets.	2	Food would have initially been acquired through bartering in markets. Following this came the development of shops selling particular commodities (for example, greengrocer, grocer, butcher, fishmonger). Then convenience stores, selling a range of foodstuffs under one roof, were developed. These grew into supermarkets and then hypermarkets supported by sophisticated national distribution systems to ensure that food is at the right place at the right time in response to consumer needs. There has been a recent revival of farmers' markets in response to lifestyle issues.
A.1.9	Explain that the food industry is now the largest industry in the world.	3	
A.1.10	Discuss the influence of market pull and technology push on the development of new food products.	3	
A.1.11	Explain that the modern food industry in developed countries is an example of a tightly controlled just-in-time system.	3	In order to get the right amount of food products in the right place at the right time, the food industry in developed countries has evolved into a tightly controlled just-in-time system operating 24 hours a day, every day. Data collection using loyalty cards produces sophisticated databases to understand the precise requirements of different geographical areas.

	Assessment statement	Obj	Teacher's notes
A.1.12	Describe organic agriculture.	2	Organic agriculture is a system of farming in which organic products and techniques are used and the use of synthetic chemicals, for example, fertilizers and pesticides, is precluded. In some countries, the word "organic" is legally protected; and in others, the term "organic agriculture" is increasingly associated with sustainability.
A.1.13	Explain that organic production is driven by market issues and problems associated with existing agricultural practices.	3	There is a growing market for organic products commanding a premium price. There have been food scares, for example, related to the use of hormones in beef production or antibiotics in chicken farms. Lifestyle issues also arise here.

A2 Designing new food products

2 hours

	Assessment statement	Obj	Teacher's notes
A.2.1	Describe the role of the design brief in the design of new food products.	2	The process of designing new food products is no different from designing other products. Design development will start with the identification of the design brief.
A.2.2	Describe how food manufacturers gain evidence to support the development of a new food product.	2	Consider data collection and analysis; comparison with existing products; and market research.
A.2.3	Construct a specification for a food product.	3	Consider ice cream and pizza.
A.2.4	Evaluate food products against specifications.	3	
A.2.5	Describe the role of taste panels in the development of the specification of a food product.	2	Taste panels are used to confirm precise requirements for key parameters of a food product, for example, sweetness, flavour, texture. The taste panel would reflect the characteristics of the target market.
A.2.6	Describe the issues involved in the scaling up of recipes from bench scale.	2	A product is designed initially as a bench-top prototype and key parameters determined using taste panels. As the volume of product increases, the recipe may need to be modified to achieve the same organoleptic characteristics. Processing differences may require, for example, more or less water in the recipe.
A.2.7	Describe the role of market testing in the development of a food product.	2	Following confirmation of the product specification, the product would be scaled up from bench scale to pilot-plant scale, so that a larger volume of product can be made and wider market testing undertaken. Following acceptance in a test market, the product would be scaled up to industrial-scale production.

	Assessment statement	Obj	Teacher's notes
A.2.8	Identify drivers for the development of food products.	2	Consider market concerns such as lifestyle factors, health and the environment, consumer demands (for example, convenience and cost), technological developments (for example, processing equipment and packaging materials), company profitability (for example, increasing market share), and entering new and non-traditional markets for specialized applications (for example, sports supplements, military purposes and space missions).
A.2.9	Outline reasons for the development of food product packaging.	2	Consider new product launch, reformulation, new pack size, branding and rebranding, promotions (price flash on packaging, special offers).

A3 Nutrition, balanced diet and health

6 hours

	Assessment statement	Obj	Teacher's notes
Proteins (1 hour)			
A.3.1	Define <i>protein</i> , <i>amino acid</i> , <i>essential</i> and <i>biological value</i> .	1	
A.3.2	Describe the role of protein in the body.	2	Protein provides essential and non-essential amino acids and acts as an energy source.
A.3.3	Identify foods of high biological value and low biological value.	2	
A.3.4	Describe how low biological value foods are complemented in different parts of the world to ensure that essential amino acid requirements are met.	2	For example, complementation of rice and beans.
A.3.5	Discuss the effect of low protein intake.	3	Stunted growth, kwashiorkor, marasmus.
Carbohydrates (1 hour)			
A.3.6	Define <i>monosaccharide</i> , <i>disaccharide</i> and <i>polysaccharide</i> .	1	
A.3.7	Describe the role of carbohydrate as an energy source in the body.	2	
A.3.8	Identify the importance of staple foods in the provision of dietary carbohydrate.	2	For example, cassava, rice, wheat, maize, potatoes and sugar.
A.3.9	Explain that carbohydrate foods are often cheap and used by people on low incomes to bulk their diet.	3	
A.3.10	Discuss the effects of low and excess carbohydrate intakes.	3	

	Assessment statement	Obj	Teacher's notes
Lipids (1 hour)			
A.3.11	Define <i>lipid, glycerol, fatty acid, essential fatty acid, saturated fatty acid</i> and <i>unsaturated fatty acid</i> .	1	
A.3.12	Describe the role of lipids in the body.	2	
A.3.13	Identify major sources of lipids in the diet.	2	
A.3.14	Discuss the effects of low and excess lipid intakes.	3	
Vitamins and minerals (1 hour)			
A.3.15	Define <i>vitamins</i> and <i>minerals</i> .	1	
A.3.16	Describe the role of water-soluble vitamins (vitamin B complex, vitamin C) in the body and their food sources.	2	
A.3.17	Describe the role of fat-soluble vitamins (vitamins A, D, E, K) in the body and their food sources.	2	
A.3.18	Describe the effects of deficiency of water-soluble vitamins on the body.	2	For example, effect of lack of B vitamins or vitamin C.
A.3.19	Describe the effects of deficiency or excess of fat-soluble vitamin intake.	2	For example, cases of excess vitamin A or D intake in children in western Europe, and effect of lack of vitamin A on eyesight in parts of central Africa.
A.3.20	Describe the functions and sources of minerals.	2	Consider calcium and iron.
A.3.21	Discuss the effect of low or excessive intake of calcium and iron.	3	
Balanced diets and health (2 hours)			
A.3.22	Define <i>micronutrient deficiency</i> and <i>malnutrition</i> .	1	
A.3.23	Explain what is meant by a balanced diet and how various food-group systems can be used to help achieve a balanced diet.	3	Consider pyramid, chalice, "five a day" and plate systems.
A.3.24	Explain how nutritional requirements and food choice change as a person gets older.	3	
A.3.25	Identify the nutrient content of typical foods.	2	
A.3.26	Discuss how health awareness affects food choice with reference to fat (quality and quantity), fibre, sugar and salt content.	3	Consumer awareness of acute and chronic health issues has a major impact through the food chain from food production to food manufacture and distribution. Understanding of such issues and health impacts has a considerable influence on patterns of food consumption.
A.3.27	Discuss the social impacts resulting from a change from traditional diets and the effect on consumer health.	3	Consider the increasing incidence of diabetes and obesity.

A4 Food spoilage and food preservation

4 hours

	Assessment statement	Obj	Teacher's notes
Food spoilage (2 hours)			
A.4.1	Define <i>food spoilage</i> .	1	
A.4.2	Explain that food spoilage can be caused by physical spoilage, chemical spoilage or microbiological spoilage.	3	Physical damage to the protective outer layer of food during harvesting, processing or distribution increases the chance of chemical or microbiological spoilage.
A.4.3	Explain that the two principal causes of chemical spoilage of food are enzymic spoilage and rancidity.	3	
A.4.4	Outline the changes that take place in enzymic spoilage.	2	
A.4.5	Explain that enzymes are responsible for some browning reactions during food preparation.	3	Consider enzymic browning and Maillard reaction.
A.4.6	Describe three types of rancidity, and outline how rancidity can be prevented.	2	Consider absorption, hydrolytic and oxidative rancidity.
A.4.7	Explain the importance of rancidity in the shelf life of food products.	3	
A.4.8	Define <i>water activity</i> (a_w).	1	
A.4.9	Describe the importance of water activity in microbial spoilage.	2	Microbial spoilage can be caused by bacteria, moulds and yeasts. Water activity of food is an important determinant of the type of food spoilage caused.
Food preservation (2 hours)			
A.4.10	List the major reasons for preserving foods.	1	Consider extension of the safe storage life of food, safety, acceptability, nutritive value, availability and economic viability.
A.4.11	Describe five methods of preserving food, including chilling, irradiation (pasteurization, sterilization, canning), vacuum packing, use of acids and preservatives, and removal of water (dehydration, use of sugar and/or salt).	2	
A.4.12	Explain how food preservation methods affect the organoleptic properties of foods.	3	Consider bread, fruit and milk.
A.4.13	Explain how food preservation methods affect the nutritional properties of foods.	3	Consider bread, fruit and milk.

A5 Food science

2 hours

	Assessment statement	Obj	Teacher's notes
Sweeteners and thickeners (1 hour)			
A.5.1	Describe the role of sugar and artificial sweeteners in the design of food products.	2	Sweetness is an important characteristic of many food products. Sweetness can be imparted by sugar or artificial sweeteners. However, sugar provides other benefits to food products. It contributes to the mouth feel of products and to their storage properties. Consider low-sugar fruit squashes.
A.5.2	Identify two artificial sweeteners.	2	Consider saccharin and aspartame.
A.5.3	Describe the role of thickeners in the design of food products.	2	Consider protein gels and starch gels.
Preservatives, antioxidants and emulsifiers (1 hour)			
A.5.4	Describe the function of preservatives in food.	2	
A.5.5	List two commonly used food preservatives.	1	
A.5.6	Describe the role of antioxidants in foods.	2	For example, the use of ascorbyl palmitate to prevent rancidity of vegetable oils.
A.5.7	List two commonly used antioxidants.	1	
A.5.8	Describe an emulsion.	2	
A.5.9	List two examples of food emulsions.	1	
A.5.10	Describe the role of emulsifiers in stabilizing food emulsions.	2	
A.5.11	List two commonly used emulsifying agents.	1	

A6 Food processing

3 hours

	Assessment statement	Obj	Teacher's notes
A.6.1	Define <i>aeration</i> , <i>coagulation of protein</i> and <i>gelatinizing</i> (gelling).	1	
A.6.2	Explain how the processes of aeration, protein coagulation and gelatinization have been used to affect the physical and/or chemical properties of bread.	3	Bread is a staple food in many cultures and is a good example in which to consider aeration, protein coagulation and gelatinization. Flour is mixed with water, causing the formation of an extended gluten network, which contributes to the elastic nature of a bread dough. Yeast produces carbon dioxide, which aerates the dough and alters the density of the bread dough and the final bread. The final stable structure of the dough is achieved by baking the bread, which coagulates the protein and gelatinizes the starch.

	Assessment statement	Obj	Teacher's notes
A.6.3	Explain the control systems used in the manufacturing process of bread.	3	<p>Large-scale food processing requires a consistent final product that meets the product design specification. Production processes can be classified into three stages: input, process and output.</p> <p>Input: the entry of raw materials for processing. Monitoring the quality of raw materials ensures a consistent starting point for food processing.</p> <p>Process: the procedures that convert the raw materials to the final product, for example, kneading, mixing, cutting.</p> <p>Output: the final product. The quality of the final product is determined by all stages of processing and each stage needs careful quality control.</p>
A.6.4	Outline the influence of scale of production on the organoleptic properties of bread.	2	<p>Craft-produced breads are generally more expensive because they are labour-intensive. These are made from raw materials (flour, water, yeast, salt) rather than from bread mixes. They are mixed by hand or with minimal use of machines and tend not to contain additives. The crust is usually chewier and the texture less uniform than for mass-produced breads. Designer breads may incorporate other ingredients, for example, bananas, olives, sun-dried tomatoes, walnuts.</p>
A.6.5	Explain how food processing enhances the value of food commodities.	3	<p>The value of farm products is increased by cleaning and cooling, processing, packaging and distribution. Compare the cost of potatoes per kilogram with potato crisps. A farmer sells potatoes to a food manufacturer and the food manufacturer makes the profit. Most of the “food dollar” comes from secondary processing of food products.</p>
A.6.6	Explain how on-farm processing can enhance farm sustainability.	3	<p>Processing raw products on the farm results in the production of higher-value consumer-ready products and gives farmers the opportunity to retain income and enhance the sustainability of the rural economy. Farmers can then capture a larger share of the “food dollar”. Small-scale food processing is more appropriate: it tends to be embedded in the local community, creates local jobs, distributes products locally and recirculates income in the local economy. However, technology transfer issues and other start-up costs cannot be ignored.</p>

A7 Food packaging and distribution

3 hours

	Assessment statement	Obj	Teacher's notes
A.7.1	Identify the functions of food packaging.	2	Distinguish between primary packaging and secondary packaging.
A.7.2	Identify a range of materials used for food packaging.	2	Consider paper, plastic, glass and metal.

	Assessment statement	Obj	Teacher's notes
A.7.3	Describe how different packaging materials affect food.	2	
A.7.4	Explain the impact of alternative packaging decisions on product cost and the environment.	3	Packaging solutions that use non-biodegradable and non-recyclable raw material, use much energy in their production and are used once and thrown away wreak havoc on the environment. Altering any of these elements can minimize environmental impact.
A.7.5	Identify current developments in packaging.	2	Consider modified atmosphere packaging and aseptic packaging.
A.7.6	Outline how food packaging is used as a promotional tool for other products.	2	
A.7.7	Explain how packaging of food products contributes to the development of brands.	3	
A.7.8	Discuss the global impact of branded products, for example, Coca-Cola®.	3	
A.7.9	Describe the purpose of food labels and the information provided on them.	2	Include nutritional content, sell-by date, storage and usage information, ingredients, warnings, volume or mass. Exclude promotional details. Only a qualitative treatment is required. The provenance of food products is increasingly important, and food labels increasingly contain the name of the farm or farmer where they were sourced.
A.7.10	Discuss the impact and effectiveness of legislation governing what should appear on food labels as a means of altering diet.	3	Diets are resistant to change due to cultural issues and habit. Food labels can provide information on sugar content, fibre content, fat content, and so on. But unless individuals choose to change, labels are unlikely to have much impact. Government initiatives may focus on fat, fibre, sugar or salt intakes to counter heart disease.

A8 People and food—lifestyle issues

3 hours

	Assessment statement	Obj	Teacher's notes
A.8.1	Discuss how religion and other cultural factors affect food choice and impact on health.	3	
A.8.2	Discuss how vegetarian and/or vegan diets affect food choice and impact on health.	3	Consider moral, religious, environmental and nutritional issues.
A.8.3	Define <i>lifestyle</i> .	1	
A.8.4	Explain how lifestyle factors affect food choice and impact on health.	3	
A.8.5	Explain how lifestyle factors have led to the development of new food products, such as snack foods and individual convenience foods.	3	

	Assessment statement	Obj	Teacher's notes
A.8.6	Explain how travel, the media and lifestyle factors have led to increased consumption of foods from other cultures and the development of an international cuisine.	3	
A.8.7	Explain how (ironically) many of the most popular ethnic dishes consumed in the developed world were traditional staple foods.	3	
A.8.8	Define <i>food allergy</i> and <i>food intolerance</i> .	1	
A.8.9	Explain how food allergies impact on diet.	3	Consider nut allergies.
A.8.10	Explain why a number of products not containing nuts are labelled with warnings that they may contain traces of nuts.	3	Consider how food processing machines are used and the potential for cross-contamination of nuts from one product to another.
A.8.11	Explain how food intolerances impact on diet.	3	Consider gluten intolerance.
A.8.12	Explain how to achieve a gluten-free diet.	3	

A9 Issues and responsibilities

3 hours

	Assessment statement	Obj	Teacher's notes
Obesity (1 hour)			
A.9.1	Define <i>body mass index</i> (BMI), <i>overweight</i> and <i>obesity</i> .	1	
A.9.2	Identify values of BMI indicating overweight and obesity.	2	A BMI between 25 and 29.9 is considered overweight. A BMI of 30 or more is considered obese. BMI can be misleading for very muscular people or for pregnant and lactating women.
A.9.3	Explain how overweight and obesity are caused.	3	Obesity is a chronic disease with a strong familial component. However, it is exacerbated by low levels of physical activity combined with high energy intakes.
A.9.4	Discuss the physiological and psychological conditions associated with overweight and obesity.	3	Obesity increases the risk of developing conditions such as high blood pressure, diabetes (type 2), heart disease, stroke, gallbladder disease and cancer of the breast, prostate and colon. Overweight and obese persons can have low self-esteem and can be victims of employment and other discrimination.

	Assessment statement	Obj	Teacher's notes
Food and cancer (1 hour)			
A.9.5	Explain that total energy intake, especially of fat-rich foods, can be an important indirect factor in determining cancer incidence.	3	Food can have positive (carcinogenic) and negative (preventive) effects. Total calorie intake has a strong positive influence on cancer incidence. Foods typical of developed countries are often fat-rich and associated with breast, colon and prostate cancers. Vegetables rich in antioxidants and fibres tend to reduce cancer incidence.
A.9.6	Explain that some naturally occurring components of food have been identified as carcinogenic.	3	Plant alkaloids and mycotoxins have been identified as being carcinogenic.
A.9.7	Explain that cooking of food can result in the production of carcinogenic substances.	3	The effect of heat on food during cooking can result in the production of carcinogenic substances, including aromatic hydrocarbons (via combustion) and heterocyclic amines. Heterocyclic amines (HCAs) have been shown to cause breast, colon and prostate cancers in rats. Some epidemiological investigations positively correlate HCA intake and cancer incidence in humans.
A.9.8	Explain that some foods, for example, garlic, contain substances that can protect against cancer.	3	A compound in garlic has been identified by the National Cancer Institute in the United States as providing protection against cancer by slowing or preventing the growth of tumour cells. Crushing, cutting or peeling garlic and processing it into oil or powder releases an enzyme called allinase. Waiting about 15 minutes between peeling and cooking garlic allows the enzyme to work. If garlic is cooked immediately after peeling, the enzyme is inactivated.
Role of governments (1 hour)			
A.9.9	Explain that chronic and acute food-related issues impact on health services.	3	Consider the impact of chronic food-related issues, for example, obesity, and acute food-related issues, for example, a food poisoning outbreak, on the health services.
A.9.10	Explain the role of governments in promoting public health.	3	Governments have a responsibility for ensuring public health. Food is a key issue in relation to public health. So governments have legislation to outline their role in protecting citizens and to identify statutory agencies to act in the consumers' interest at any stage in the food production and supply chain through monitoring food safety.
A.9.11	Explain that a major role of government is to raise public awareness of food-related health issues.	3	Governments run campaigns to raise public awareness of food-related health issues and provide educational materials. For example, these include the health risks associated with obesity and how to treat obesity, the dangers of eating under-cooked foods, and how to ensure that food is properly cooked.

HL A10 Food poisoning**5 hours**

	Assessment statement	Obj	Teacher's notes
A.10.1	Identify two main categories of food-transmitted diseases: food-borne infections and food poisoning.	2	<p>Food-borne infections are caused by parasitic organisms (for example, worms, protozoa, bacteria and viruses) that use food to gain access to the human host. The parasites do not grow in the food but in the human host. Only a small dose is required to cause illness. Some of these diseases can be transmitted via contaminated water, directly from animals or indirectly from infected objects, such as toilets. Worm infections include tapeworm and roundworm. Proper meat inspection in abattoirs and good standards of hygiene reduce the incidence of these diseases. Amoebic dysentery is caused by protozoan infection.</p> <p>Food poisoning occurs because certain foods are naturally toxic (for example, rhubarb leaves) or because they have become contaminated with toxic chemicals or food poisoning bacteria. Certain fungi are toxic. Toxic chemical contamination can occur if food is harvested too soon after spraying with pesticides and other chemicals. Bacterial food poisoning is the most significant food-transmitted disease in developed countries and is a far greater hazard than food-borne infections. However, in developing country contexts food-borne infections are important.</p>
A.10.2	Identify two main categories of bacterial food poisoning: infective bacterial food poisoning and toxin-type bacterial food poisoning.	2	<p>In infective bacterial food poisoning, food becomes infected with certain bacteria, for example, <i>Salmonella</i>. These grow in food (due to improper storage) and when consumed they continue to grow in the gut of the person who ate the food. Their growth and death in the gut causes the symptoms of food poisoning.</p> <p>Toxin-type food poisoning occurs when bacteria growing in food, for example, <i>Staphylococcus aureus</i>, produce toxins. If food containing the toxins is consumed, then food poisoning occurs.</p>
A.10.3	Outline the signs and symptoms of food poisoning.	2	
A.10.4	Explain how lifestyle factors contribute to the increased incidence of food poisoning.	3	In developed countries, more people eat outside their own homes, with a resulting increase in food poisoning. Additionally, there is increased consumption of ready meals, which, if not stored or reheated correctly, can contribute to food poisoning.
A.10.5	Describe how food poisoning can be avoided.	2	Preventing the contamination of foods with food-poisoning bacteria and/or preventing the growth of bacteria in the food.
A.10.6	Define <i>food hygiene</i> .	1	

	Assessment statement	Obj	Teacher's notes
A.10.7	Explain how good personal hygiene can help to prevent the contamination of food with food-poisoning bacteria.	3	
A.10.8	Explain how the design of food preparation areas can help to prevent the contamination of food with food-poisoning bacteria.	3	
A.10.9	Describe "high-risk" foods.	2	Foods (for example, milk, mayonnaise, meat, fish) that can support the growth of food-poisoning bacteria are termed "high-risk" foods. To prevent the growth of food-poisoning bacteria, high-risk foods should be kept hot or cold but never warm.
A.10.10	Describe the temperature danger zone for bacterial growth.	2	The temperature danger zone is between 10°C and 63°C. Food-poisoning bacteria will not usually grow below 10°C because there is insufficient warmth to support growth and the bacteria are inactive. Above 63°C, food-poisoning bacteria, but not their spores, are killed by the heat.
A.10.11	Explain that cooking is an important means of controlling bacterial growth.	3	Proper cooking depends on four considerations: sufficiently high cooking temperature; sufficient time for cooking; the size of the food being cooked (food is a poor conductor of heat, and therefore large items of food, for example, joints of meat, need longer cooking times than smaller ones); and the initial temperature of the food (some frozen foods, for example, frozen poultry, which can be contaminated with <i>Salmonella</i> , need to be defrosted before cooking, otherwise the centre temperature will never be high enough to kill any bacteria present).
A.10.12	Explain how an understanding of food poisoning influences the design of individual convenience foods.	3	

HL A11 Genetically modified organisms and food production

5 hours

	Assessment statement	Obj	Teacher's notes
General principles (1 hour)			
A.11.1	Define <i>genetically modified organism</i> (GMO).	1	
A.11.2	Identify the factors underpinning the genetic modification of foods.	2	Consider issues relating to agricultural processes (for example, enhanced yield and improved resistance to attack by pathogens), enhanced storage characteristics or enhanced eating quality.
A.11.3	Explain the principles underpinning genetic modification.	3	Identification and isolation of the gene to be modified and introduction of the modified gene into the DNA of the crop using a vehicle for the transfer of DNA.

	Assessment statement	Obj	Teacher's notes
A.11.4	Discuss issues relating to the traceability of genetically modified crops.	3	
A.11.5	Discuss the ethical issues underpinning public concerns about the safety of genetically modified foods.	3	How does genetic modification change the food? Are genetically modified foods safe to eat from nutritional and toxicological perspectives? Will they cause allergic reactions? What are the potential impacts on the environment? Will the genes be transferred to other organisms and what are the implications?
A.11.6	Discuss the importance of acceptance by the general public in establishing a market for a food product.	3	Any product must have a market to remain viable. The public are naturally wary about any new food product, and it takes time to establish a product in the marketplace. Uptake of the product must be rapid enough for the product to maintain its commercial viability.
Case study: The FlavrSavr™ tomato (2 hours)			
A.11.7	Describe the significance of the FlavrSavr tomato.	2	In 1994, the first genetically modified food was approved by the FDA (US Food and Drug Administration) to go to market. The FlavrSavr tomato was modified by Calgene (a biotechnology company) using antisense technology.
A.11.8	Describe the advantages of FlavrSavr tomatoes over traditionally grown tomatoes.	2	Traditional tomatoes must be harvested while still green to maintain their firmness during transport to the supermarket. The tomatoes are then sprayed with ethylene to ripen them. FlavrSavr tomatoes are designed so they can ripen on the vine longer while maintaining firmer skin, thus producing a fuller-flavoured tomato on the supermarket shelves.
A.11.9	Explain how antisense technology impacts on gene expression.	3	Antisense RNA down-regulates the expression of specific genes. In tomatoes the enzyme polygalacturonase (PG) causes depolymerization of pectin in the cell wall of the tomato and results in softening of the ripe tomato. PG is encoded by the PG gene, which is expressed during ripening. The introduction of an antisense PG gene results in down-regulation of endogenous PG enzyme.
A.11.10	Explain how FlavrSavr tomatoes were produced.	3	The first step in this process involved the isolation of the PG gene from the tomato. It was then cloned using reverse transcriptase to produce antisense PG gene, which was introduced into a plasmid (a bacterial virus). The plasmid was transferred into a bacterium <i>E. coli</i> to multiply the number of antisense genes. The DNA was then transferred into the bacterium <i>Agrobacterium tumefaciens</i> , which acted as a vehicle for the transfer of the antisense PG gene into the tomato genome. In an organism with both sense and antisense mRNA, the two will encounter one another, binding due to their complementary sequences and cancelling each other out.

	Assessment statement	Obj	Teacher's notes
A.11.11	Explain how the seeds carrying the antisense PG gene were identified.	3	Kanamycin resistance was used as a selectable marker to identify plants carrying the antisense PG gene. Thus, only plants that have taken up the kanamycin resistance gene survive when grown in the presence of kanamycin, permitting selection of plants that have taken up the antisense PG gene.
A.11.12	Explain why kanamycin-resistant genes are approved as selectable markers for crop genetic engineering.	3	Kanamycin resistance genes are approved as selectable markers on grounds that the antibiotic kanamycin is no longer in use. A selectable marker is a gene inserted into a cell or organism to allow the modified form to be selectively amplified while unmodified organisms are eliminated. In crop genetic engineering the selectable marker is used in the laboratory to identify cells or embryos that bear the genetic modifications that the engineer wishes to commercialize. The selection gene is used once briefly in the laboratory but thereafter the genetically modified (GM) crop has the unused marker gene in each and every one of its cells.
A.11.13	Explain how public concerns resulted in the withdrawal of the FlavrSavr tomato from the market.	3	Public concern surrounded the introduction of the FlavrSavr tomato into the market. In 1997, the tomato was withdrawn from the market.
Case study: Roundup Ready™ crops (2 hours)			
A.11.14	Describe the significance of the resistance of crops to the herbicide Roundup™.	2	The herbicide Roundup, which contains glyphosate as its active ingredient, works by inhibiting an enzyme (5-enolpyruvyl shikimate-3-phosphate synthetase, EPSPS) that is necessary for the plant to synthesize particular aromatic amino acids, and thus kills the plant. Roundup Ready™ crops, for example, genetically modified (GM) Roundup Ready soybeans, have a bacterial version of this enzyme incorporated into them, which gives them protection from the pesticide. Roundup Ready crops can then be sprayed with the pesticide, killing the weeds and leaving the crop unaffected.
A.11.15	Identify a range of crops that have been genetically modified to make them Roundup-resistant.	2	For example, soybeans, wheat and maize.
A.11.16	Explain how the testing of the safety of Roundup Ready crops is undertaken.	3	Analyse country-specific reports applying for authorization to market Roundup Ready crops.
A.11.17	Explain the importance of independent evaluation in assessment of the appropriateness of the testing of GM crops.	3	Analyse critiques of the testing of GM crops.
A.11.18	Discuss the ethical issues underpinning the labelling of GM crops and their products.	3	Consider why producers would not want to label GM crops and their products, and why ethically it is important that they should.

HL A12 Food security**5 hours**

	Assessment statement	Obj	Teacher's notes
A.12.1	Define <i>poverty</i> and <i>human development index</i> .	1	
A.12.2	Explain the significance of poverty.	3	Poverty is the world's biggest killer in its own right and contributes to disease and death through the greater likelihood of living in a poor environment.
A.12.3	Outline the importance of targeted policy interventions.	2	Agrarian reform policies and other targeted interventions are designed to address disease and enhance life expectancy and health of poor communities.
A.12.4	Identify the Millennium Development Goals (MDGs) in relation to poverty and food security.	2	
A.12.5	Evaluate progress towards the MDGs.	3	
A.12.6	Explain how the human development index combines key poverty-related issues into a holistic measure that can be used at a country level to evaluate poverty alleviation strategies.	3	
A.12.7	Define <i>food insecurity</i> , <i>undernourishment</i> and <i>undernutrition</i> .	1	
A.12.8	Describe undernourishment and undernutrition as distinct measures used to estimate the numbers of hungry people.	2	
A.12.9	Explain how undernourishment and undernutrition are calculated.	3	
A.12.10	List the criteria for food security.	1	Sufficient food is available, supplies are relatively stable and those in need of food can obtain it.
A.12.11	Identify the global extent of undernourishment.	2	800 million people in developing countries and approximately 34 million people in developed countries are chronically undernourished.
A.12.12	Explain the importance of local, national, international and global strategies in combating food insecurity.	3	
A.12.13	Discuss the ethical issues surrounding the development of a global policy concerning food security.	3	
A.12.14	Explain the role of the Food and Agriculture Organization (FAO) of the United Nations (UN) in combating food insecurity.	3	
A.12.15	Evaluate the progress of the work of the FAO in relation to food security.	3	

Option B: Electronic product design (30/45 hours)

Core material: B1–B7 are core material for SL and HL (30 hours).

Extension material: B8–B10 are extension material for HL only (15 hours).

B1 General principles

6 hours

	Assessment statement	Obj	Teacher's notes
B.1.1	Define <i>voltage, current, charge</i> and <i>resistance</i> .	1	
B.1.2	Calculate I , Q or t based on the equation $I = Q/t$.	2	
B.1.3	Describe Ohm's law.	2	Ohm's law is the mathematical relationship linking electric current, resistance and voltage, $V = IR$.
B.1.4	Calculate V , I or R based on the equation $V = IR$.	2	
B.1.5	Identify resistors using colour codes.	2	E12 series: black (0), brown (1), red (2), orange (3), yellow (4), green (5), blue (6), violet (7), grey (8), white (9). Most resistors have four bands: the first band gives the first digit; the second band gives the second digit; the third band indicates the number of zeros; the fourth band shows the tolerance of the resistor, but can be ignored for most circuits. If the third band is gold, then the value is multiplied by 0.1; and if it is silver, multiply by 0.01.
B.1.6	Calculate total resistance for resistors in series.	2	$R_{\text{total}} = R_a + R_b + R_c + \dots$
B.1.7	Calculate total resistance for resistors in parallel.	2	$\frac{1}{R_{\text{total}}} = \frac{1}{R_a} + \frac{1}{R_b} + \frac{1}{R_c} + \dots$
B.1.8	Explain electrical power in terms of voltage and current.	3	$P = VI$, not energy per unit time.
B.1.9	Calculate P , V or I based on the equation $P = VI$.	2	
B.1.10	Explain the importance of power ratings for components.	3	Exceeding the power rating for a component damages the component.
B.1.11	Identify suitable power ratings for components in circuits.	2	Calculate the power dissipated by a given component in a given circuit, then select a round number above this value to give a safety margin.
B.1.12	Distinguish between alternating current (ac) and direct current (dc).	2	An alternating current (ac) is an electrical current whose magnitude and direction vary cyclically, usually in the form of a sine wave. Direct current (dc) is a constant current.
B.1.13	Measure the amplitude of a given alternating waveform using an oscilloscope.	1	

	Assessment statement	Obj	Teacher's notes
B.1.14	Deduce the frequency of a given alternating waveform having measured its period using an oscilloscope.	3	
B.1.15	Explain that, in remote areas of developing countries, electricity supply is based on localized supply not a national grid system.	3	Remote areas of developing countries rely on generators for ac supply, and solar panels for battery-based low-voltage dc supply, as there is not a national grid system. This has implications for portable electronic equipment.
B.1.16	Explain that, in developed countries, there will be a national grid, although the voltage will vary between countries, with countries adopting either the US standard or the UK standard.	3	The US standard is 120 V/60 Hz. The UK standard is 240 V/50 Hz.
B.1.17	Explain how differences in electrical voltage can impact on the design of electrical and electronic products.	3	
B.1.18	Explain the implications for aid agencies of there being no national grid in remote areas of developing countries.	3	
B.1.19	State the unit of capacitance.	1	The unit for capacitance is farad (F). This is a very large unit, and so for most practical applications of the type we would expect students to use, the unit is microfarad (μF).
B.1.20	Calculate total capacitance for capacitors in series.	2	$\frac{1}{C_{\text{total}}} = \frac{1}{C_a} + \frac{1}{C_b} + \frac{1}{C_c} + \dots$
B.1.21	Calculate total capacitance for capacitors in parallel.	2	$C_{\text{total}} = C_a + C_b + C_c + \dots$
B.1.22	Define <i>time constant</i> .	1	$T = CR$
B.1.23	Calculate the time constant for circuits.	2	
B.1.24	Explain the importance of the time taken for a capacitance to lose half its voltage.	3	The time taken for the voltage to halve is the time delay for a logic circuit to switch.

B2 Digital logic

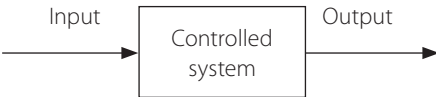
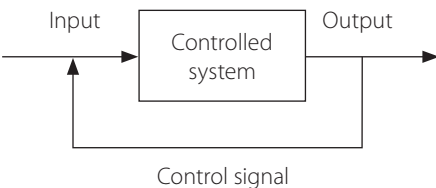
5 hours

	Assessment statement	Obj	Teacher's notes
B.2.1	Explain the differences between a digital and an analogue signal.	3	Digital is either on/off, high/low, or 1/0. Analogue involves a continuously varying signal that can have any value, positive or negative; the only limit is the value of the power supply.

	Assessment statement	Obj	Teacher's notes
B.2.2	Explain how a digital signal can be generated from an analogue signal.	3	Consider the use of a Schmitt trigger (not gate) switching its output cleanly and decisively when the analogue input voltage at its input rises above the upper switching threshold or falls below the lower switching threshold.
B.2.3	Describe the significance of binary code in digital electronics.	2	Binary is base 2. There are two possible states, 0 or 1. A binary code can be stored, processed or transmitted.
B.2.4	Describe how the two possible output states of a logic gate can be used as a switch.	2	Logic gates have one of two outputs: 1 (high), and 0 (low). Switching from one state to the other will turn a circuit on or off.
B.2.5	Draw circuit symbols for digital logic gates.	1	Consider AND, OR, NAND, NOR, NOT, XOR.
B.2.6	Draw truth tables for digital logic gates.	1	Draw truth tables for the six logic gates in B.2.5.
B.2.7	Identify Boolean expressions for digital logic gates.	2	AND $Q = A \cdot B$ OR $Q = A + B$ NAND $Q = \overline{(A \cdot B)}$ NOR $Q = \overline{(A + B)}$ NOT $Q = \overline{A}$ XOR $Q = A \oplus B$
B.2.8	Design solutions to practical problems using digital logic gates.	3	Produce a truth table for a given design problem. For a given truth table, design a logic circuit. Maximum of four logic gates. Maximum three inputs per logic gate.
B.2.9	Design time delays by applying switches and CR circuits as the input to logic gates.	3	Assume logic gates are CMOS with a 5 V supply, that is, the input switching threshold is 2.5 V. Hence the time delay for switching will be $0.7CR$.

B3 Control

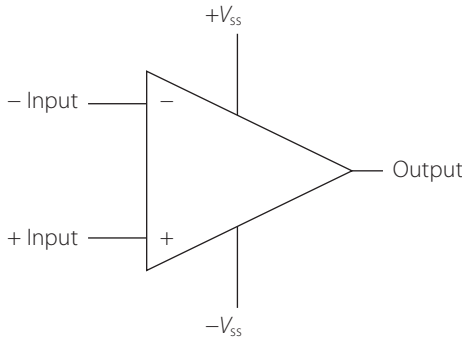
2 hours

	Assessment statement	Obj	Teacher's notes
B.3.1	Draw a block diagram for an open loop system.	1	
B.3.2	Describe the limitations of open loop systems.	2	Lack of feedback would mean it is not possible to determine if the system has responded as required. The system is unable to respond to external influences.
B.3.3	Draw a block diagram for a closed loop control system.	1	

	Assessment statement	Obj	Teacher's notes
B.3.4	Explain how feedback is used in a closed loop control system.	3	A sensor provides information about the current state of the output from a system. This is compared to the input requirements, producing an error signal, which is in turn processed to drive the output.
B.3.5	Explain the advantages of closed loop systems over open loop systems.	3	A closed loop system overcomes the limitations of open loop systems.
B.3.6	Explain why most systems use negative rather than positive feedback.	3	Negative feedback will stabilize systems, for example, a lathe spinning at a particular speed will slow down when put under load. The sensor will detect the slowing down and the feedback will re-establish the required speed of the lathe. Positive feedback is used when rapid, decisive switching is required to filter out electrical interference, or an oscillating output is required.

B4 Operational amplifiers

6 hours

	Assessment statement	Obj	Teacher's notes
B.4.1	Draw the circuit symbols for, and describe the functions of, a range of electrical components.	2	Consider resistor, thermistor, LDR (light-dependent resistor), variable resistor, diode, cell, push switches, SPST (single pole, single throw) switches, SPDT (single pole, double throw) switches, lamp, motor, LED (light-emitting diode), loudspeaker, buzzer and capacitor.
B.4.2	Draw the circuit symbol for an operational amplifier (op amp).	1	Label the inverting and non-inverting inputs, output and split rail power supply. Assume $\pm 15\text{ V}$. 
B.4.3	Define <i>positive saturation</i> and <i>negative saturation</i> .	1	
B.4.4	Draw a circuit for an op amp used as a comparator.	1	
B.4.5	Explain the operation of a comparator.	3	If the non-inverting input is of a higher voltage than the inverting input, the output will be in positive saturation (and vice versa).
B.4.6	Describe how resistors can be used to produce a voltage divider circuit.	2	$\frac{V_s R_2}{(R_1 + R_2)} = V_{\text{out}}$

	Assessment statement	Obj	Teacher's notes
B.4.7	Describe how $\frac{V_s R_2}{(R_1 + R_2)} = V_{\text{out}}$ <p>can be used to generate a reference voltage for one input of a comparator.</p>	2	
B.4.8	Explain how a thermistor or a light-dependent resistor (LDR) can be used as either of the two resistors in $\frac{V_s R_2}{(R_1 + R_2)} = V_{\text{out}}$ <p>to produce a temperature or light sensor.</p>	3	Assume an NTC (negative temperature coefficient) thermistor.
B.4.9	Draw a circuit for an op amp used as a non-inverting amplifier.	1	
B.4.10	Calculate the gain of a non-inverting amplifier.	2	$V_{\text{out}} = \left(1 + \frac{R_f}{R_a}\right) V_{\text{in}}$
B.4.11	Draw the transfer characteristic for a non-inverting amplifier.	1	
B.4.12	Draw an output waveform of a non-inverting amplifier, for a given input waveform and gain.	1	
B.4.13	Explain the effect that saturation has on the output waveform for a non-inverting amplifier.	3	Over $\pm 13\text{ V}$ the output waveform is saturated and can go no higher. This is commonly referred to as clipping.
B.4.14	Calculate the gain of an inverting amplifier.	2	$V_{\text{out}} = -\frac{R_f}{R_a} V_{\text{in}}$
B.4.15	Draw the transfer characteristic for an inverting amplifier.	1	
B.4.16	Draw an output waveform of an inverting amplifier, for a given input waveform and gain.	1	
B.4.17	Explain the effect that saturation has on the output waveform of an inverting amplifier.	3	

B5 Programmable interface controllers

5 hours

	Assessment statement	Obj	Teacher's notes
PIC technology (3 hours)			
B.5.1	Define <i>programmable interface controller</i> (PIC).	1	
B.5.2	Describe why PICs are ubiquitous in almost all modern electronic products.	2	A generic PIC can be programmed to replace the function of hard-wired circuits. Reprogramming of a PIC enables extension of the design life of an electronic product through enhanced functionality. Generic PICs can be programmed to use different numbers of analogue and digital inputs and digital outputs depending on the design context. Different generic PICs have particular numbers of inputs and outputs; some PICs have more memory than others. PICs are inexpensive.
B.5.3	Explain why in many design contexts only a small proportion of the capacity of a PIC is utilized.	3	For one-off and small volume production, it is more cost-effective to stock one sort of PIC of a higher specification than is likely to be used.
B.5.4	Identify reasons why PICs are particularly applicable for portable electronic products.	2	They have low power requirement, so suitable for battery-operated applications. Complex circuits can be synthesized through the software rather than multiple logic chips.
B.5.5	Discuss why PICs can be regarded as a sustainable technology.	3	They extend the life of a product through downloading software upgrades, so can overcome issues of planned obsolescence. Low volumes of non-toxic, readily available raw material (silicon) are used in their production. Reduce battery consumption during life. Low energy requirements for manufacture. Less material is required to encase the products and their battery supply.
B.5.6	Explain how PIC technology has improved the electronic systems in car design.	3	Consider brakes, steering, climate control, traction and fuel injection systems.
Electronics and health (2 hours)			
B.5.7	Explain how an audiogram represents an individual's hearing, which may be normal at some frequencies and with losses at other frequencies.	3	
B.5.8	Explain that digital hearing aids are able to divide incoming sound into distinct bands, which are individually selected for amplification.	3	
B.5.9	Identify the key elements of a digital hearing aid.	2	Microphone, appropriate filters for separating frequency bands, analogue-to-digital converter, and processing to amplify certain frequency bands (compare to a graphic equalizer).
B.5.10	Explain how a PIC can contribute to the customization of a hearing aid.	3	Ear prescriptions change over time and hearing generally gets progressively worse with age. A PIC hearing aid can be periodically reprogrammed (unlike eye-glasses, which have a limited product life).

B6 Communication systems

4 hours

	Assessment statement	Obj	Teacher's notes
B.6.1	Define <i>bandwidth, multiplexing, modulation and demodulation</i> .	1	
B.6.2	Explain the principles of frequency division multiplexing.	3	Internet service providers (ISPs) buy bandwidth. The bandwidth can be split into a number of smaller bandwidths sufficiently wide to meet the requirements of the user. Early connections used 56 kbps, which required a bandwidth of 56 kHz. Broadband Internet links (at the time of writing this guide) have a much higher capacity and therefore require a wider bandwidth, for example, 500 kHz or 2 MHz. If the ISP had bought 100 MHz of bandwidth, their link would support fifty 2 MHz users or about two thousand 50 kHz users. The 2 MHz link is a much faster link (high-speed broadband).
B.6.3	Explain the principles of time division multiplexing.	3	Each user's signal is digitally coded into short-duration pulses. Pulses for each user are sent in order along the link. The receiver must be synchronized with the transmitter to allow correct reassembling of the bits to produce the different signals.
B.6.4	Explain the limitations of copper wires for information transfer.	3	Copper wires have limited bandwidth capacity and therefore can only support a small number of simultaneous users. Hence it is not cost-effective. Electrical noise is electromagnetic in nature and therefore copper wire links are very vulnerable to interference. Ohmic losses in copper cables are significant, and so when signals need to be transmitted over considerable distances many signal amplifiers are needed. Copper is a scarce resource and therefore copper wires are expensive. Copper wires require maintenance.
B.6.5	Describe an optical fibre.	2	A cable made from coated glass (or plastic) with a thermoplastic overcoat, a strengthening member and a PVC jacket.
B.6.6	Describe how fibre optic cables are able to transfer information.	2	The signal is modulated onto a carrier of optical frequency. As light can be contained within the cable via total internal reflection, the signal travels along the cable with low losses.
B.6.7	Explain how fibre optics are able to transfer information in large quantities.	3	Optical frequencies are very high (of the order of 3×10^{14} Hz), so there is a huge bandwidth capacity, typically many GHz. This volume of users can make the laying down of optical fibres between Europe and America cost-effective.

	Assessment statement	Obj	Teacher's notes
B.6.8	Draw a block diagram for an optical fibre transmission link.	1	Electrical pulses are used to pulse a laser (or LED), which directs the pulses into the optical fibre link for transmission. At the receiver, the optical pulses are converted back to electrical pulses. (See http://www.arcelect.com/fibercable.htm)
B.6.9	Identify three types of optical fibre.	2	There are three types of fibre optic cable commonly used: single-mode, multimode (step index and graded index) and plastic optical fibre (POF).
B.6.10	Explain the difference between a single-mode and a multimode optical fibre.	3	A single-mode optical fibre is narrow, typically 10 μm diameter, and only allows a single path through the fibre. A multimode fibre is 5–10 times the diameter of a single-mode fibre, so there are multiple paths for light to travel through the fibre, resulting in different path lengths and hence dispersion (overlapping of light pulses).
B.6.11	Identify the advantages and disadvantages of each type of optical fibre.	2	Single-mode fibres have larger bandwidth but need a more sophisticated (and expensive) narrow spectrum light source. Also more precise lenses are needed at all entry and exit points. Single-mode fibre links can be long because they do not suffer from dispersion, whereas long multimode links need regeneration of the signal at regular intervals. POF cables are a recent (at the time of writing) development that offer similar performance to glass cables at lower cost, but only for short links.
B.6.12	Explain the advantages of optical fibres for information transfer.	3	They are made out of sand. Not subject to electromagnetic interference. Need amplifying much less frequently. Low maintenance. Optical fibres are much thinner and lighter than copper cables, so very long length can be handled and installed in one go.
B.6.13	Describe how satellite systems are able to transfer information.	2	The information is modulated onto an electromagnetic carrier wave, which propagates through free space from the transmitting ground stations in the satellite's footprint (area of coverage), where it is amplified and retransmitted to the receiving ground stations also in the footprint.
B.6.14	Identify the advantages and disadvantages of satellite systems.	2	The advantage of a satellite link is its mobility. Users can be added anywhere in the footprint. Disadvantages of a satellite link are its expense. It has a lower capacity because it uses microwave (of the order of 10^{10} Hz) not optical frequencies. Satellite links are subject to interference from environmental factors, for example, thunderstorms. Security is an issue, as unauthorized users in the footprint may be able to gain access to the link.

B7 Global standards for digital electronic products

2 hours

	Assessment statement	Obj	Teacher's notes
B.7.1	Explain the importance of global standards for digital electronic product manufacturers.	3	Digitization (reducing signals to binary, 1s and 0s) of text, voice and graphics enables these forms of communication, traditionally delivered by distinct modes of transmission, to be treated as digital streams and delivered by a range of modes. Use of generic standards reduces development costs for manufacturers and increases the interoperability of different devices.
B.7.2	Describe how companies either exploit a generic data system or develop their own system.	2	Consider the differences between different digital music data systems.
B.7.3	Explain how standards have impacted on multifunctionality of personal entertainment products.	3	Consider convergence of mobile phones, cameras, music players and video.
B.7.4	Explain the benefits of the adoption of generic standards for the manufacturer.	3	Consider reduction in use of materials, product loyalty, wider market, distribution costs and investment in research and development (R&D).
B.7.5	Explain the benefits of the adoption of generic standards for the user.	3	Consider costs and function.
B.7.6	Discuss the implications of company-specific standards in the marketplace.	3	Consider brand, accessories and patents.

HL B8 The smart home

5 hours

	Assessment statement	Obj	Teacher's notes
General principles (3 hours)			
B.8.1	Outline the concept of a smart home.	2	A smart home is a residence that uses a home controller to integrate the various home automation systems.
B.8.2	Identify two electronic systems that could be incorporated into a smart home environment.	2	Consider heating and lighting systems.
B.8.3	Identify input–process–output devices appropriate to the design of heating and lighting systems in a smart home.	2	
B.8.4	Explain how modern electronic computer systems are used to monitor and perform functions in the home.	3	Integrating home systems allows them to communicate with one another through the home controller (a computer), thereby enabling single button and voice control of the various home systems simultaneously, in pre-programmed scenarios or operating modes.
B.8.5	Identify a range of applications relevant to the implementation of a smart home.	2	For example, locking and unlocking doors, filling a bath, tracking the Sun with a solar panel, and opening and closing ventilators and windows.

	Assessment statement	Obj	Teacher's notes															
B.8.6	Explain how PICs are integrated into control circuits to implement the smart home concept.	3	For a PIC to influence the real world, it has to interface with it. This is achieved through the use of a range of output devices to control environments, for example, relays, motors, stepper motors, servos, heaters, fans, air conditioning units, modems, sounders. A PIC can have a number of inputs, both digital and analogue, and hence it is able to monitor a variety of different sensors simultaneously. A PIC can make "intelligent" decisions based on pre-programmed protocols and react in order to maintain, or change, the environment. A PIC can store data so, for example, it can control the environment in a way customized to an individual's personal preferences.															
B.8.7	Identify a range of input options for locking and/or unlocking a door.	2	An infrared remote transmitter with a unique code or a smart card wall-mounted key-pad entry or linked to a central computer with predefined times.															
B.8.8	Explain how a door can be locked and/or unlocked electronically.	3	<p>A bolt can be made to move in or out by an electromagnet known as a solenoid. If current flows in one direction through the solenoid coil, the bolt will move out. Making the current flow in the opposite direction will make the bolt move back in. Two PIC outputs are needed to achieve this:</p> <table><tr><td>Output 1</td><td>Output 2</td><td>Effect</td></tr><tr><td>0</td><td>0</td><td>bolt does not move</td></tr><tr><td>0</td><td>1</td><td>bolt moves in one direction</td></tr><tr><td>1</td><td>0</td><td>bolt moves in opposite direction</td></tr><tr><td>1</td><td>1</td><td>bolt does not move</td></tr></table> <p>A suitable current amplifier (made from transistors) is also needed, because the PIC outputs cannot by themselves provide sufficient current.</p>	Output 1	Output 2	Effect	0	0	bolt does not move	0	1	bolt moves in one direction	1	0	bolt moves in opposite direction	1	1	bolt does not move
Output 1	Output 2	Effect																
0	0	bolt does not move																
0	1	bolt moves in one direction																
1	0	bolt moves in opposite direction																
1	1	bolt does not move																
B.8.9	Explain the role of valves to control water flow, for example, into a bath.	3	Central computer pre-programmed with a user's required volume of water and temperature and possibly times at which the bath is required to be filled. Flow meter to determine volume of water dispensed. Temperature sensors to adjust, via a solenoid valve, the relative flow rates of the hot and cold water.															
B.8.10	Identify reasons for using smart technology to open and close windows or blinds.	2	Monitoring and controlling an environment is not just for the convenience and comfort of the consumer; it can also make a home more environmentally friendly by reducing fuel consumption. It can also provide support for users with physical disabilities, or the elderly.															
B.8.11	Explain how a motor could be applied to open or close ventilators, windows or blinds.	3	Light sensor, external moisture sensor to detect if it rains, for example, in a greenhouse, bedroom or kitchen.															

	Assessment statement	Obj	Teacher's notes
Home security (2 hours)			
B.8.12	Identify a range of input sensors applicable to a home security system.	2	PIR (passive infrared) sensors, micro-switches, vibration sensors, pressure pads, video monitors, infrared or laser light gates.
B.8.13	Identify a range of output devices applicable to a home security system.	2	Strobe lights, sirens, auto dial for security service.
B.8.14	Describe the role of video monitors in a home security system.	2	Monitors can be placed in key locations and linked to a single location for "real-time" observation and for storage, so video footage can be reviewed only when necessary.
B.8.15	Define <i>bit rate</i> , <i>resolution</i> and <i>refresh rate</i> .	1	
B.8.16	Calculate the bit rate requirement in a given situation.	2	<p>Calculations will assume a digital image comprising a number of rows, each row being a number of pixels. Simple black-and-white images need one bit to represent each pixel; colour images need three bits to represent each pixel (one for each primary colour). Systems producing higher-quality images will also need a number of bits for each pixel to give intensity information (for example, four levels of intensity would need two bits per pixel, eight levels of intensity would require three bits per pixel).</p> <p>Bit rate requirement = number of rows × pixels per row × bits per pixel × refresh rate × number of monitors using link.</p>
B.8.17	Explain the significance of the limited bit rate capacity of a home security data link.	3	Consider the number of monitors sharing a link, the resolution of the images produced (black-and-white or grey scale) and the refresh rate of the system.
B.8.18	Explain how the specification for security systems would differ for different applications.	3	Consider how the brief for the design of security systems would differ between a system for a celebrity and one for a block of flats.
B.8.19	Discuss the ethical issues relating to the use of home security systems.	3	Consider security, convenience, cost, intrusiveness and issues relating to the trade-off between privacy and security.

HL B9 Disposal of electronic products

5 hours

	Assessment statement	Obj	Teacher's notes
B.9.1	Define <i>product stewardship</i> , <i>dematerialization</i> , <i>service costs</i> and <i>upgradeability</i> .	1	
B.9.2	Discuss the issues associated with advanced electronic technology and product life cycle.	3	There are an increasing number of waste electronic products. In the US alone about 40 million personal computers are sold each year and about 20 million become obsolete. Electronic and electrical products may contain hazardous or toxic materials, which can cause environmental problems. Computer monitors and televisions are hazardous because they contain significant amounts of lead. Printed circuit boards contain hazardous metals such as lead, chromium, cadmium and mercury, with significant variation depending on the board. Batteries in electronic and electrical products may contain lead, mercury and cadmium. Mercury-containing components like switches and relays are found in some electronic and electrical products.
B.9.3	List the implications of product stewardship for manufacturers.	1	Designing products that are more easily disassembled and recycled. Using less toxic and more recycled and recyclable materials. Designing products that last longer, with parts that can be replaced or upgraded. Taking back used products for rebuilding or recycling. Developing an environmentally sound collection and recycling infrastructure. Incorporating the costs for collection and recycling into the product price so they are paid by electronics consumers at the point of sale not by ratepayers at the point of disposal.
B.9.4	Explain why electronic products are designed for disassembly.	3	Consider disassembly in the reuse and recycling of components. Pressure from the impact of product take-back policies.
B.9.5	Discuss strategies that can be used for the disassembly of electronic products.	3	Using temporary fittings, shredding, avoiding toxic substances and use of metals.
B.9.6	Explain how legislation controls the disposal of electronic products.	3	
B.9.7	Explain the impact of product take-back legislation on the design of electronic products.	3	
B.9.8	Discuss the advantages and disadvantages of electronic disposal legislation for the designer, consumer and manufacturer.	3	
B.9.9	Compare reuse and recycling of electronic products.	3	
B.9.10	Explain how the miniaturization of electronic components has helped promote design for dematerialization.	3	

	Assessment statement	Obj	Teacher's notes
B.9.11	Discuss how rising service costs are key contributors to the replacement of electronic products in preference to repair.	3	Consider call-out charges, cost of parts, disassembly and efficiency of products.
B.9.12	Outline how new developments in technology enhance the upgradeability of electronic products.	2	Consider short-life electronic products and separable units.
B.9.13	Discuss the advantages and disadvantages of upgradeability for the designer, manufacturer and consumer.	3	Consider costs, brand, fashion and function.
B.9.14	Describe digital photography.	2	Taking pictures with a digital camera and storing and printing them on digital devices. Celluloid film is replaced by digital storage media: flash memory modules, floppy disks or CD-Rs. Images can be transferred to a local computer for printing or uploaded to the Internet for viewing and printing.
B.9.15	Discuss how digital photography can be used to minimize waste.	3	For example, the use of digital photography allows photos to be taken, shared and printed out with the use of fewer chemicals and less waste than traditional methods.

HL B10 Converging technologies

5 hours

	Assessment statement	Obj	Teacher's notes
B.10.1	Define <i>converging technology</i> and <i>nanotechnology</i> .	1	
B.10.2	Identify current nanotechnology applications.	2	Commercial nanotechnologies are based on nano-sized particles. Nanoscale zinc oxide is used as a sunscreen to absorb ultraviolet light; the small particles are invisible to the naked eye, so the lotion is clear. Zinc oxide also has antimicrobial properties and is used for bacteria-resistant fabrics and surfaces. Small particles can coat the surface of clothing fabrics making them stain-repellent. Silver nano-crystals can be used to produce antimicrobial bandages or to coat the surfaces of refrigerators, air conditioners and washing machines and act as antibacterial and antifungal agents. Plastic nano-composites are used for strong, light and rust-proof car components. Toyota recently began using nano-composites in bumpers, making them 60% lighter and twice as resistant to denting and scratching. Artificial bone composites have been made from nano-crystalline calcium phosphate with strength in compression equal to that of stainless steel.

	Assessment statement	Obj	Teacher's notes
B.10.3	Identify how converging technologies might enhance human performance.	2	<p>Transforming factories into intelligent environments to maximize benefits of mass production and custom design. Controlling automobiles, ensuring military superiority, and enabling new sports, art forms and modes of interaction between people through fast broadband human-machine interfaces. Enhancing awareness of a person's health, environment, chemical pollutants, potential hazards and information of interest through comfortable, wearable sensors and computers. Robots and software agents will operate on principles compatible with human goals, awareness, and personality. Enabling people from diverse backgrounds and abilities to learn more reliably and quickly. Facilitating individual and team communication and cooperation across traditional barriers of culture, language, distance, and professional specialization; and increasing the effectiveness of groups, organizations, and multinational partnerships. Making the human body more durable, healthier, more energetic, easier to repair, and more resistant to stress, biological threats and aging. Products will be made from materials that have exactly the desired properties, including the ability to adapt to changing situations, high energy efficiency, and environmental friendliness. Compensating for physical and mental disabilities. Enhancing national security through lightweight, information-rich war fighting systems, capable unmanned combat vehicles, adaptable smart materials, invulnerable data networks, superior intelligence-gathering systems, and effective measures against biological, chemical, radiological, and nuclear attacks. Providing instantaneous global access to practical and scientific information tailored for most effective use by particular individuals. Enhancing creativity of engineering, artistic, architectural and design activities. Exploiting genetic engineering to benefit human welfare; and building consensus on ethical, legal, and moral issues into the process. Facilitating space travel by efficient launch vehicles, robotic construction of extraterrestrial bases, and profitable exploitation of the resources of the Moon, Mars, or near-Earth approaching asteroids. Increasing business, education and government effectiveness through new organizational structures and management principles based on fast, reliable communication. Improving the awareness of average persons and policy makers of the cognitive, social, and biological forces operating on human society, enabling better adjustment, creativity, and daily decision-making. Enhancing agricultural yields and reducing food spoilage through networks of cheap, smart sensors that constantly monitor the condition and needs of plants, animals, and farm products. Safer, cheaper, faster transportation due to high-efficiency vehicle designs, and the use of synthetic materials and machines designed for optimum performance. Transforming education through a unified but diverse curriculum based on a comprehensive, hierarchical intellectual paradigm.</p>

	Assessment statement	Obj	Teacher's notes
B.10.4	Explain how converging technologies might expand human cognition and communication.	3	"The Human Cognome Project" is a multidisciplinary effort to understand the structure, functions and potential enhancement of the human mind. Priority areas include: personal sensory device interfaces; enriched communities through humanized technology; learning how to learn; and enhanced tools for creativity.
B.10.5	Explain how converging technologies might improve human health and physical capabilities.	3	Convergence of nanotechnology and biotechnology will enhance research and development of treatments for human diseases: nanotechnology-based implants and regenerative biosystems as replacements for human organs or for monitoring of physiological well-being; nanoscale machines and comparable unobtrusive tools for medical intervention; multi-modality platforms for increasing sensorial capabilities, particularly for visually and hearing impaired people; brain-to-brain and brain-to-machine interfaces; and virtual environments for training, design and forms of work unlimited by distance or the physical scale on which it is performed.
B.10.6	Explain how converging technologies might benefit national defence.	3	Data linkage and threat anticipation; unmanned combat vehicles; war fighter education and training; responses to chemical, biological, radiological and explosive threats; war fighter systems; non-drug treatments to enhance human performance; and applications of human-machine interfaces.
B.10.7	Describe "The Communicator".	2	A conceptual converging technology system called "The Communicator" has been designed to enhance the efficiency and creativity of group communication. It would remove barriers to communication caused by physical disabilities, language differences, geographic distance, and variations in knowledge.

	Assessment statement	Obj	Teacher's notes
B.10.8	Identify the key components of "The Communicator".	2	Consider the individual information component; the avatar component; and the environmental interface component. The individual information component will model an individual, including preferred modes of interaction—language spoken, preferred sensory channel, limitations on input and output (for example, sight or hearing difficulties), cognitive capability (learning speed, learning style, area of expertise), leisure activities, history of important social events. The avatar component will be 3D, human-sized and human-like (face/emotions) virtual people able to take on any human form (race, gender and age). Its persona, mode of communication and language should modify over time as it learns the best method of communication or training for each individual and should be able to be placed and projected wherever needed. The environmental interface component will create opportunities to enhance personalized communications and education. Characteristics of how humans interact with information and technology can be viewed as constraints, or they can be viewed as strengths that convergent technology can play to. For example, if an individual is good at detecting anomalies or patterns in data, the technology would enhance this capability.
B.10.9	Identify key design considerations in the implementation of "The Communicator".	2	Key design considerations include very high-speed cable or wireless communications and a wearable human–computer interface to provide augmented reality in office, schoolroom, factory or field situations.
B.10.10	Explain how technologies will be used in the implementation of "The Communicator".	3	Nanotechnology will enable the high-speed computational capabilities, wearable components that consume little energy, and pervasive sensors. Biotechnology will enable the interfaces to monitor the physical status of participants and is required for the design of human-friendly technologies. Information technology will enable data management and transmission, translation across modalities and languages, and development of avatars and intelligent agents. Cognitive science will provide the understanding of effective learning styles, methods for elimination of bias, and a direction for searching for common values to promote social cooperation.

	Assessment statement	Obj	Teacher's notes
B.10.11	Identify potential applications for avatars.	2	Consider: representing the human participants in a group to each other; representing autonomous computerized agents that perform particular functions of the information and communication system; going into dangerous situations, for example, to negotiate with a criminal holding a hostage; functioning as a resident nurse to the sick or as a companion to the elderly; perceiving the presence of biohazards or radiation in a dangerous environment; acting as a tutor, for example, via a haptic suit could teach movements for dance, athletics, weaponry or surgery.
B.10.12	Explain the advantages of “The Communicator” for global cooperation.	3	It would enhance the effectiveness of communication between humans and promote cooperation in schools, corporations, government agencies, and across the world. It would enhance group creativity and productivity, cognitive engineering and developments related to networked society.
B.10.13	Explain the challenges of converging technologies for education systems.	3	To meet the coming challenges, scientific education needs radical transformation from elementary school through to postgraduate training. Convergence of previously separate scientific disciplines and fields of engineering cannot take place without the emergence of new kinds of people who understand multiple fields in depth and can work intelligently to integrate them. New curriculums, new concepts to provide intellectual coherence, and new forms of educational institutions will be necessary.
B.10.14	Explain the responsibilities of governments in the development of converging technologies.	3	Governments must provide leadership and coordinate the work of other institutions. They should support new multidisciplinary developments while sustaining the traditional disciplines that are essential for success. Ethical, legal, moral, economic, environmental, workforce development and other societal implications must be addressed from the beginning. Consensus on the implications of converging technologies and the way to deal with them should involve scientists and engineers, social scientists and a broad coalition of professional and civic organizations. Research on societal implications must be funded, and the risk of potential undesirable secondary effects must be monitored to anticipate issues and take corrective action.
B.10.15	Evaluate progress towards converging technology concepts.	3	In 2001 converging technology was a concept with a 20-year timescale for implementation. It is impossible to predict the progress that will be made towards converging technology goals over the life of this guide.

Option C: CAD/CAM (30/45 hours)

Core material: C1–C5 are core material for SL and HL (30 hours).

Extension material: C6–C8 are extension material for HL only (15 hours).

C1 The impact of CAD on the design process

6 hours

	Assessment statement	Obj	Teacher's notes
C.1.1	Outline the use of different software applications.	2	Consider CAD drawing, 2D, 3D, rendering and different types of modelling.
C.1.2	Discuss the advantages and disadvantages of using software applications in different design contexts.	3	Consider product design, architecture and graphic design.
C.1.3	Define <i>animation</i> and <i>virtual reality</i> .	1	
C.1.4	Compare animation and virtual reality.	3	Refer to different design contexts. Consider costs, client needs and development time.
C.1.5	Discuss the cost-effectiveness offered by animation and virtual reality.	3	Consider how this helps to reduce full-scale prototyping, which leads to a reduction in tooling costs, labour costs, energy and materials.
C.1.6	Describe haptic technology.	2	Also known as force feedback technology. Haptic technology works by using mechanical actuators to apply forces to the user. By simulating the physics of the user's virtual world, it is possible to compute these forces into real time.
C.1.7	Define <i>motion capture technology</i> .	1	
C.1.8	Outline how various input devices are used by a CAD system.	2	Details of how these devices communicate with the computer are not required. (Input devices should include a scanner, 3D scanner, digital camera and graphics tablet.)
C.1.9	Explain how haptic technology and motion capture have enhanced design capability.	3	Haptic technology allows the user to become part of a computer simulation and to interact with it, enabling the designer to observe the user's performance, so as to design a better outcome. Haptic technology can also be used in situations where it may prove difficult to train in the real environment. Haptic technology is also used in feedback devices used in home entertainment consoles. Capturing a number of users' movements will allow designers to design better ergonomic products. Motion capture allows the designer to understand the users' physiological requirements.

	Assessment statement	Obj	Teacher's notes
C.1.10	Outline how 3D pictorial drawings are the primary mode of design in CAD.	2	CAD packages no longer ask the user to draw in an orthographic view. Software has been developed to allow users to design from any 3D view. 3D facilities allow complex screen images that can be annotated to create a range of useful data. The data can be used in CAM systems.
C.1.11	Explain how the initial 3D drawings can be used to generate other types of drawing.	3	For example, orthographic drawings and presentation virtual product images.
C.1.12	Describe the processes used to revolve and extrude sketches in CAD.	2	Revolve: allows the users to revolve a sketch around an axis. The revolve can be between 0° and 360°. The Extrude Profile command creates a feature by extruding a sketch profile to a given dimension.
C.1.13	Annotate a 3D CAD drawing to identify workplanes, faces, edges and features.	2	
C.1.14	Define “top down” modelling.	1	
C.1.15	Define “bottom up” modelling.	1	
C.1.16	Compare “bottom up” and “top down” CAD modelling.	3	Bottom up: starts with an initial sketch in which the designer builds the design. Top down: starts with a 3D shape in which the designer removes material to build the design.
C.1.17	Define <i>surface modelling</i> .	1	
C.1.18	Define <i>solid modelling</i> .	1	
C.1.19	Explain the differences between solid and surface modelling techniques.	3	Solid modelling techniques contain more information for the designer in order to produce a 3D model using CNC (computer numerical control) or RP (rapid prototyping) technologies. Surface modelling has no wall thickness.
C.1.20	Define <i>finite element analysis</i> (FEA).	1	
C.1.21	Explain how FEA can be used to show the forces acting upon an object while in use.	3	For example, the maximum load of a vehicle and the stresses acting upon the vehicle from the differences in terrain.
C.1.22	Compare finite element analysis with real-life testing.	3	Consider costs, type of environment, weather and the user when testing vehicles.
C.1.23	Outline how CAD can aid cost analysis in the planning to manufacture.	2	

C2 CAM systems

8 hours

	Assessment statement	Obj	Teacher's notes
C.2.1	Describe additive manufacturing techniques.	2	The manufacture of 3D parts by depositing molten material in a series of layers.
C.2.2	Describe subtractive manufacturing techniques (wasting).	2	The manufacture of 3D parts by removing (cutting) unwanted material from a block.

	Assessment statement	Obj	Teacher's notes
C.2.3	Compare subtractive and additive manufacturing techniques.	3	Subtractive manufacturing techniques remove material (waste) to manufacture parts. Additive products have minimal wastage and the end product is built from a number of parts or a continuous extrusion of material.
C.2.4	Describe a laser cutter.	2	A device that is able to laser cut and engrave 2D shapes.
C.2.5	Describe rapid prototyping (RP).	2	A device that is able to produce a complete product including internal details.
C.2.6	Describe a plotter cutter.	2	A device that is used to cut 2D shapes from card and vinyl.
C.2.7	Explain how CNC (computer numerical control) routers, milling machines, laser cutters and plotter cutter machines can be used to manufacture a variety of outcomes (subtractive).	3	Consider a range of products that have been made using subtractive CNC equipment, for example, signs, vacuum form moulds, flat-pack furniture.
C.2.8	Explain how RP (rapid prototyping) machines can be used to manufacture a variety of outcomes (additive).	3	Consider how rapid prototyping has been used to reduce development time and how one-off products are made for different situations.
C.2.9	Explain a situation in which it would be advantageous to use subtractive or additive manufacturing when making a product.	3	Use product examples to illustrate the advantages of both processes.
C.2.10	Explain how a variety of tools can be used to make a complex outcome.	3	Multi-tool CNC machines are used where the outcome requires more than one cutting process. For example, a CNC lathe is able to drill, ream, cut and part-off.
C.2.11	Discuss the advantages and disadvantages of using large- or small-diameter tools when machining.	3	Large-diameter tools cut a larger area, thus reducing the amount of time needed to complete a task. However, large-diameter tools leave large radiuses in internal corners. Small-diameter tools have to use a higher spindle speed, and feed rate is normally slower, but they are able to perform more intricate jobs.
C.2.12	Define <i>machine tool step variable</i> .	1	
C.2.13	Outline how the machine tool step over variables can determine the output quality of a product.	2	When using a ball nose cutter for 3D profiling, the tool step over should be reduced to give a better quality finish.
C.2.14	Describe raster, spiral and pocket cutting to manufacture.	2	Raster cutting is where the tool path cuts in straight X,Y paths. Spiral cutting is where the tool path is circular, which is especially useful for round and curved objects. Pocket cutting is where the tool path is determined by individual Z coordinates across the product.
C.2.15	Discuss how machining paths alter the quality of a product and amount of time required in order to produce it (consider raster, spiral and pocket machining).	3	Use post-processing software to simulate the amount of time needed to cut a product using raster, spiral and pocket machining techniques.

	Assessment statement	Obj	Teacher's notes
C.2.16	Discuss the limitations of using three-axis machining when making a 3D product.	3	Consider undercuts and a flat base.
C.2.17	Define <i>G code</i> .	1	
C.2.18	Outline how a 3D CAD drawing is converted into a CNC file using G codes.	2	3D CAD drawings are converted to G code using post-processor software such as GeoCam. Drawings are exported as an STL file, which triangulates the design, allowing the software to determine the path of X,Y,Z coordinates.
C.2.19	Define <i>feed speed</i> .	1	
C.2.20	Outline how feed speeds change depending on material and size of tool.	2	Metals are cut at a slower feed rate than that of wood due to the hardness of the material. A larger diameter tool will waste more material, thus causing its feed speed to be reduced. Spindle speed is also altered to suit material and tool diameter.
C.2.21	Outline how limitations of tooling can affect the manner in which an object can be designed and manufactured.	2	The limitations of tool length and diameter affect the final design and manufacture of a product. Internal corners will all have radius and deep pockets will not be able to be cut by small-diameter tools.

C3 The impact of CAD/CAM on manufacturing

5 hours

	Assessment statement	Obj	Teacher's notes
C.3.1	Define <i>numerical control</i> .	1	
C.3.2	Explain how a numerically controlled (NC) machine aids manufacturing.	3	An NC machine is able to reproduce manufactured parts in large quantities; NC machines can be used reliably in situations requiring continuous operation in areas that would normally expose operators to hazardous conditions.
C.3.3	Define <i>computer numerical control</i> (CNC).	1	
C.3.4	Compare numerical control and computer numerical control.	3	Numerical control machines are not connected to a computer. An operator inputs the data manually. A CNC machine accepts and operates from computer data. A CNC machine offers greater flexibility over that of NC. Products are made accurately. CNC machines are economical to operate, but initial costs are high.
C.3.5	Explain how a CNC machine further aids manufacture.	3	Global communication systems allow for the CNC machining data to be sent anywhere in the world. The flexibility of a CNC machine reduces down-time between batch runs or one-off production. CNC machines can be incorporated into a CIM (computer integrated manufacturing) environment to control individual requirements and consumer needs. (Refer to greater flexibility, reprogrammability, multi-machine control, tooling and multi-axis machining.)

	Assessment statement	Obj	Teacher's notes
C.3.6	Describe two- and three-axis machining processes.	2	Two-axis CNC lathe: workpiece motion (rotary axis) and X,Y axes for cutting. Three-axis machining for milling, routing and engraving: Z axis for depth of cut, X and Y axes for direction of cut.
C.3.7	Describe four- and five-axis machining processes.	2	Four-axis machining is a lathe with a milling head attachment; X,Y,Z axes plus an additional rotary motion. Five-axis machining is a milling machine with three linear axes (X,Y,Z) with rotation about two axes.
C.3.8	Outline how milling machines and routers can be interfaced in a CAD/CAM system.	2	
C.3.9	Discuss the issues faced by the designer and manufacturer when choosing CNC equipment.	3	Costs, flexibility, maintenance, tooling, training, speed and quality of finish.
C.3.10	Outline how a CNC lathe is interfaced in a CAD/CAM system to produce a 3D model.	2	Consider a suitable product to be made on a lathe and outline the advantages and disadvantages to the operator.
C.3.11	Define <i>computer integrated manufacture</i> (CIM).	1	
C.3.12	Describe how CAD/CAM can be integrated into a CIM system.	2	
C.3.13	Outline one example of a CIM system.	2	For example, car production. Vehicle ordered to customer specification. Materials and third-party parts ordered to allow JIT (just-in-time) manufacture. Assembly checked for quality throughout, allowing for minimal wastage.
C.3.14	Discuss the advantages and disadvantages of CIM to consumers and manufacturers.	3	Manufacturer: initial set-up costs, staff morale, storage and reduction of waste. Customer: cost-effective product, quality and individual needs.

C4 Rapid prototype manufacture

6 hours

	Assessment statement	Obj	Teacher's notes
C.4.1	Describe stereo lithography.	2	Stereo lithography (SLA) is a 3D printing process that uses a vat of photosensitive resin and a vertically moving platform. It uses a laser beam, directed onto the surface of the photosensitive resin, to print the pattern of the current model layer by hardening the photosensitive resin. The platform then moves down by a layer thickness so the next layer can be printed.
C.4.2	Describe wet rapid prototyping.	2	A technique that uses a fluid support structure that can be washed and drained away.
C.4.3	Describe dry rapid prototyping.	2	A technique that uses break-away supports.

	Assessment statement	Obj	Teacher's notes
C.4.4	Describe laminated object manufacture (LOM).	2	LOM machines take the sliced CAD data from the 3D model and cut out each layer from a roll of material, using a laser or plotter cutter. These sliced layers are glued together to form the model, which is either built on a movable platform below the machine or on pins when using card.
C.4.5	Describe solid object printing.	2	Solid object printing, in particular wax modelling, employs inkjet deposition technology. A linear array of nozzles deposits molten wax on a platform, layer by layer, to build up the 3D model.
C.4.6	Describe fuse deposition modelling (FDM).	2	An FDM machine is basically a CNC robot that holds a small extrusion head. The extrusion head moves back and forth along a platform, building up a 3D model by feeding heated plastic wire through the extrusion head.
C.4.7	Describe select laser sintering (SLS).	2	SLS is a 3D printing process based on sintering. A CO ₂ laser is used to sinter a thin layer of heat-fusible powder that gradually builds up the 3D model.
C.4.8	Compare wet and dry rapid prototype techniques.	3	Wet techniques can be used for more intricate internal construction where it would be difficult to break away supports. Dry techniques use a break-away structure, which can be difficult to remove from detailed areas.
C.4.9	Explain the benefits of being able to rapid prototype a product instead of using other CAM techniques.	3	Consider product design, speed, time, costs, accuracy and waste.
C.4.10	Discuss the limitations of rapid prototyping for volume-produced products.	3	Consider the internal structure of a product, and number of components.
C.4.11	Discuss how rapid prototyping (RP) benefits trials, testing and final part manufacture.	3	Consider reduced development time and costs, and user trials.
C.4.12	Compare SLS, LOM and FDM rapid prototype processes.	3	Consider speed, time, costs, accuracy and surface finish.
C.4.13	Describe different design contexts where SLS, LOM and FDM would be applicable.	2	Consider quality, cost and accuracy of outcome.

C5 CAD/CAM products

5 hours

	Assessment statement	Obj	Teacher's notes
Packaging (2 hours)			
C.5.1	Describe the use of CAD and rapid prototyping in the development of electronic product housing.	2	Consider the reduction of research and development work when designing the casing for electronic products.
C.5.2	Discuss the benefits of using CAD and rapid prototyping to the designer and manufacturer of electronic products.	3	Consider costs, development time, working models, manufacturing strategies, number of components, use of materials and market research.

	Assessment statement	Obj	Teacher's notes
C.5.3	Describe the use of rapid prototyping in the development of cosmetics packaging.	2	Consider testing, reduction in waste and user requirements.
C.5.4	Discuss the benefits of using rapid prototyping to the designer and manufacturer of cosmetics products.	3	Consider weight and thickness of material, ergonomics, manufacturing strategies and market research.
C.5.5	Discuss how CAD and rapid prototyping has reduced the life cycle of packaged products.	3	For example, style and method of assembly, and use of standardized fittings.
Jewellery (1 hour)			
C.5.6	Describe how the use of CAD has changed the jewellery industry.	2	Consider settings, patterns, size and virtual products.
C.5.7	Discuss the benefits of using CAD/CAM to the designer and manufacturer of jewellery.	3	Consider production of master, lost wax casting, reproduction, mass customization, size and range of products.
C.5.8	Explain how CAD/CAM has improved the type and range of jewellery products available to the consumer.	3	Consider use of scanning 2D images, 3D sculpture, and complementary sets.
Furniture (2 hours)			
C.5.9	Outline a piece of furniture that can be manufactured by CAD/CAM or by a more traditional process.	2	Consider flat-pack furniture compared to traditional cabinet-making techniques.
C.5.10	Compare the two manufacturing processes for a chosen piece of furniture.	3	Refer to skills involved, efficiency of production, quality control, precision, flexibility and economics.
C.5.11	Evaluate the product manufactured by the two manufacturing processes.	3	Refer to complexity of design, quality and cost.
C.5.12	Discuss the benefits of using CAD/CAM in the design and manufacture of flat-pack furniture.	3	Assembly of parts in CAD drawings, order of assembly, quality control, mass customization.
C.5.13	Discuss how CAD/CAM has affected consumer choice when purchasing furniture.	3	Include interior design packages to model and design environments.
C.5.14	Outline an area in which a single task robot could be used in the manufacture of flat-pack furniture.	2	Counting accessories and adding fixings.
C.5.15	Discuss the issues associated with using manufactured boards and natural timber when using CAM to produce furniture.	3	Consider chipping, grain, warping, the clamping of material, quality of profile.
C.5.16	Outline how the increased use of CAD/CAM in furniture manufacture has developed the need for a wider range of knock down fittings.	2	Flat-pack furniture.
C.5.17	Describe how exploded view CAD drawings have helped consumers when assembling components.	2	Consider the use and quality of pictorial view sequence diagrams.

HL C6 Materials**3 hours**

	Assessment statement	Obj	Teacher's notes
C.6.1	Identify the characteristics of materials that make them appropriate for CAM.	2	Warping, stable, porous, uniform grain structure.
C.6.2	Explain that some materials require lubrication for effective CAM.	3	Quality of finish, tool wear, expansion.
C.6.3	Compare CAM to more traditional manufacturing techniques.	3	Consider initial investment, training, working environment, flexibility, communication and wastage.
C.6.4	Explain how CAD/CAM has improved quality assurance.	3	Repeatable quality and a reduction in the amount of tolerance.
C.6.5	Identify a range of suitable materials that could be used for modelling purposes in a CAM system.	2	Modelling wax, high-density foam, manufactured board and card.
C.6.6	Discuss the issues associated with using MDF as a modelling material in a CAM system.	3	Consider health and safety, tooling, feed speed and surface finish.
C.6.7	Discuss how modelling wax can be used in a CAM system to aid jewellery production.	3	Modelling wax can be machined by CNC and then used to produce a master for lost wax casting.
C.6.8	Discuss the issues associated with using metals in a CAM system.	3	Consider feed speed, depth of cut, coolant and tooling.
C.6.9	Outline how surface modelling techniques let consumers test before they buy.	2	Changes of colour and texture give a better aesthetic view of what a product may look like.

HL C7 Robots**6 hours**

	Assessment statement	Obj	Teacher's notes
C.7.1	Define <i>industrial robot</i> .	1	
C.7.2	Describe the role of the robot in an industrial environment.	2	Consider accuracy, quality control, reduction of human exposure to hazards, speed and flexibility when linked to a CIM system.
C.7.3	Describe the use of robots in industrial conditions that would be unsuitable for humans.	2	For example, laser welding, high temperatures.
C.7.4	Describe how robots can perform new processes in extreme conditions.	2	New techniques have been developed to make use of robots that withstand high temperatures and other hazardous conditions.
C.7.5	Outline how robots have contributed to quality control in the manufacturing industry.	2	Reduction in tolerances, no fatigue, 24-hour manufacture.
C.7.6	Discuss the issues associated with replacing the human workforce with robots.	3	Loss of jobs, high initial investment, training and maintenance costs.

	Assessment statement	Obj	Teacher's notes
C.7.7	Explain how robots have reduced waste in manufacture.	3	Better quality outcomes and constant monitoring of working tolerances.
C.7.8	Define <i>artificial intelligence</i> .	1	
C.7.9	Outline how feedback plays an important role in developing artificial intelligence.	2	Consider environmental feedback and quality control.
C.7.10	Discuss the advantages of replacing hydraulic robots with electrical robots.	3	Electrical robots are quieter, work to closer tolerances and require less maintenance.
C.7.11	Discuss the social and moral issues of using robots to manufacture goods.	3	Cost of goods; planned obsolescence; developing countries; technologically advancing countries move further away from those in the developing world.
C.7.12	Identify where robots can be used in automated car manufacturing.	2	Transporting parts, welding, assembly and quality control.
C.7.13	Explain why robots work in teams to complete an operation.	3	Consider speed and the need to hold parts when completing other operations.
C.7.14	Outline the differences between single-task and multi-task robots.	2	For example, sophistication of programming.
C.7.15	Distinguish between robots that perform single tasks and reprogrammable robots that undertake a variety of tasks.	2	
C.7.16	Discuss how developments in robotics mean that robots are now used for small-scale production as well as volume production.	3	

HL C8 Social, moral, economic and environmental aspects

6 hours

	Assessment statement	Obj	Teacher's notes
C.8.1	Discuss how CAD allows for working 24 hours a day every day across time zones.	3	Consider global communication systems and how these can be used to enable 24-hour working in different nations.
C.8.2	Discuss how CAD allows for flexible working in any location.	3	Consider the use of laptops, mobile communication systems and the ability to work while on the move.
C.8.3	Outline how CAD has changed the role of the designer in the design process.	2	A designer multi-tasks, for example, creates a variety of models; integrates the business of design with the creative aspects.
C.8.4	Outline how CAD has changed the nature of the designer–client relationship.	2	Closer relationship; exchange of information and ideas; client more involved in the design process.
C.8.5	Outline how CAD has changed the nature of design education.	2	More scope for students, for example, sophisticated modelling techniques.
C.8.6	Discuss the effect of CAM on the labour force.	3	Consider unemployment and 24-hour working.

	Assessment statement	Obj	Teacher's notes
C.8.7	Outline how CAM has changed the type and range of product.	2	Consider accuracy, sophistication and reliability.
C.8.8	Explain why some products are manufactured by CAM while others may be made using traditional manufacturing techniques.	3	Consider costs, complexity of outcome, flexibility of workforce, assembly and the use of mechanization.
C.8.9	Discuss how rapid prototyping and other CAM techniques reduce the use of natural resources.	3	Consider additive manufacture, reduced research and development, and the manufacture of sample goods to be used in trials.
C.8.10	Discuss the implications of computerized manufacture on the infringement of copyright and patent laws.	3	Include ease of copying, security and changing designs.

Option D: Textiles (30/45 hours)

Core material: D1–D10 are core material for SL and HL (30 hours).

Extension material: D11–D13 are extension material for HL only (15 hours).

D1 Raw materials

4 hours

	Assessment statement	Obj	Teacher's notes
D.1.1	Define <i>fibre</i> and <i>yarn</i> .	1	
D.1.2	List two subdivisions of textile fibres.	1	Natural and synthetic textile fibres.
D.1.3	Describe the process of spinning fibres into yarn.	2	
D.1.4	Identify the characteristics of three natural textile fibres.	2	Consider cotton, wool and silk for absorbency, strength, elasticity, and the effect of temperature.
D.1.5	Describe the sources of the three natural textile fibres considered in D.1.4.	2	
D.1.6	Describe how each of the natural textile fibres considered in D.1.4 is harvested and converted into yarn.	2	
D.1.7	Identify the characteristics of three synthetic textile fibres.	2	Consider nylon, polyester and Lycra® for absorbency, strength, elasticity, and the effect of temperature.
D.1.8	Describe the sources of the three textile fibres considered in D.1.7.	2	
D.1.9	Describe how each of the fibres considered in D.1.7 is produced and converted into yarn.	2	

D2 Fabric manufacturing and finishing techniques

5 hours

	Assessment statement	Obj	Teacher's notes
D.2.1	Define <i>fabric</i> .	1	
D.2.2	Describe the knitting process for producing fabric.	2	
D.2.3	Describe the weaving process for producing fabric.	2	
D.2.4	Describe the lace-making process for producing fabric.	2	
D.2.5	Describe the felting process for producing fabric.	2	
D.2.6	Describe the bonding process for producing fabric.	2	
D.2.7	Identify the characteristics of the fabrics produced by each of the techniques listed in D.2.2–D.2.6.	2	Consider dimensional stability, feel, drape, strength-to-weight ratio, and transparency.
D.2.8	Describe how cutting and machining are used for wasting fabric to produce components for textile products.	2	
D.2.9	Describe techniques for joining natural and synthetic fabrics.	2	Consider sewing, heat fusion, fasteners and adhesives.
D.2.10	Explain why the manufacture of some textile garments is still done by hand.	3	
D.2.11	Describe the coating process for finishing fabrics.	2	
D.2.12	Describe the embossing process for finishing fabrics.	2	
D.2.13	Describe the dyeing process for finishing fabrics.	2	
D.2.14	Describe the bleaching process for finishing fabrics.	2	
D.2.15	Explain how each of the techniques identified in D.2.11–D.2.14 is used to modify the performance characteristics of textile fabrics.	3	Consider fire retardancy, waterproofing, soil release, ease of maintenance, fashion and bleaching.
D.2.16	Explain how the desired characteristics are developed in textile products through treating the raw material, manufacturing and finishing.	3	Consider raw material, additives, manufacturing, ripstop, finishing and waterproofing.

D3 Evolution of textile processing

2 hours

	Assessment statement	Obj	Teacher's notes
D.3.1	Discuss craft production in relation to textiles prior to the Industrial Revolution.	3	Refer to sources of power, raw materials, labour, type of products and markets.
D.3.2	Outline the changes in textile production caused by mechanization.	2	Refer to sources of power, machinery, labour, working conditions and markets.
D.3.3	Outline the changes to textile production caused by automation.	2	Refer to sources of power, machinery and nature of textile products.
D.3.4	Explain why the textile industry expanded significantly during the time of the Industrial Revolution.	3	Consider availability of raw materials, scale of production, expansion of markets, distribution links and rise of the merchant (middle) class.
D.3.5	Explain the further expansion of the textile industry due to automation.	3	Consider new materials, global markets, changes in geographical manufacturing locations and economic considerations.

D4 Designing textiles with CAD

3 hours

	Assessment statement	Obj	Teacher's notes
D.4.1	Outline how the use of CAD has enabled the design of a wide range of textile products.	2	Complex designs, modification, and repetition.
D.4.2	Discuss how the use of CAD has increased choice for consumers.	3	Individual requirements, for example, one-off design and mass customization.
D.4.3	Describe the process of applying laser image transfer (LIT) to textile products.	2	
D.4.4	Discuss the limitations and benefits of using LIT when designing textile products.	3	
D.4.5	Describe the sublimation printing process for textile products.	2	
D.4.6	Discuss the limitations and benefits of using sublimation when designing textile products.	3	Consider durability, image quality, and substrate material.

D5 Manufacturing textiles with CAM

2 hours

	Assessment statement	Obj	Teacher's notes
D.5.1	Outline the key areas in which CAM can be used to manufacture textile products.	2	Consider embroidery, sewing, cutting, knitting and weaving.
D.5.2	Outline how sewing and knitting machines and looms can be interfaced in a CAD/CAM system to produce textile products.	2	Refer to scanning, layers, management of materials and interfaces.

	Assessment statement	Obj	Teacher's notes
D.5.3	Discuss how the use of CAM in the textile industry has helped to minimize waste.	3	Consider nesting of garment components and quality control.
D.5.4	Describe how a CNC embroidery machine is able to convert a photographic image into a textile decoration.	2	
D.5.5	Describe how CAM has enabled the development of mass customized textile products in the global marketplace.	2	

D6 Medical products

3 hours

	Assessment statement	Obj	Teacher's notes
D.6.1	Define <i>prosthesis</i> and <i>biocompatibility</i> .	1	
D.6.2	Outline the importance of vascular prostheses.	2	The rising number of patients with vascular disease has meant an increase in the number of operations that involve the replacement of arteries. Today, large-diameter arteries can be easily replaced, but small-diameter arteries pose more of a problem. Autografts (removing and using the patient's veins) have been used. The development of synthetic vascular grafts with identical chemical and physical properties to real arteries can eliminate the need for autografts. Research is multidisciplinary and involves surgeons and specialists from the medical products and textile industries.
D.6.3	Outline the specification for the design of a textile vascular graft.	2	<p>The graft needs to satisfy the following engineering and functional criteria:</p> <ul style="list-style-type: none"> • its surface should not encourage the formation of blood clots • should incorporate elements to impart compliance and elasticity • should be designed to maintain long-term tensile strength • must be biocompatible or have the ability to be healed by the patient • must be easy to handle • should have the capacity for uniform volume production • should be able to withstand long shelf storage • should be able to withstand repeated sterilization • should be available in a variety of sizes.

	Assessment statement	Obj	Teacher's notes
D.6.4	Outline the materials used in vascular grafts.	2	Early attempts to replace arteries with rigid plastic tubes failed because stresses at the joint between the artery and the graft resulted in thrombosis or hemorrhage. Woven textile structures and plastic foams, being more impermeable to blood and more flexible and compliant than rigid plastic tubing, have been used. Elastic fibres were used but did not have adequate mechanical and physical properties. Nylon is still used, but polyester is chosen more frequently because of its good mechanical and chemical properties; its low moisture absorption also gives good resistance to deterioration. To give more elasticity to the tube, elastomeric yarns can be blended with the polyester. Tubes can be woven, knitted or braided.
D.6.5	Explain developments in the design and manufacture of textile vascular prostheses.	3	Developments include production of a collagen framework on a Teflon® tube (like the steel-beam skeleton of a skyscraper); and incubation of some smooth muscle cells from the patient on the collagen superstructure to produce a user-friendly, rejection-resistant artery. Eventually the collagen would dissolve but the muscle cells of the new artery would thrive and continually renew themselves according to the established structural pattern. Arteries have to withstand intense, pulsing pressures, and so it is necessary to replicate the ribbed construction and circumferential strength of the natural artery. Computer models are used to optimize the design and to simulate fabrication. Computer modelling suggests that arteries should be more thickly walled at the ends to make them easier to attach.
D.6.6	Explain the importance of biocompatibility in the development of textile vascular prostheses.	3	
D.6.7	Explain how implant materials are tested for biocompatibility.	3	
D.6.8	Explain why regulatory bodies, such as the Food and Drugs Authority in the US, do not approve materials in isolation but approve medical devices made from these materials for specific purposes.	3	There is no absolute biocompatibility. A material appropriate for one application may not be safe for another application.

D7 Recreational products

2 hours

	Assessment statement	Obj	Teacher's notes
D.7.1	Define <i>biomimetics</i> .	1	
D.7.2	Outline the use of biomimetics in the development of sports clothing.	2	Speedo® Fastskin®. swimsuits imitate shark skin.

	Assessment statement	Obj	Teacher's notes
D.7.3	Explain the advantages and disadvantages of using biomimetics in sports clothing.	3	Unfair advantages to some athletes; special made-to-measure requirements.
D.7.4	Outline how the development of textiles has contributed to the improved performance of athletes.	2	Refer to lightweight and breathable fabrics, for example, Lycra®, Gore-Tex®, Musto® HPX.
D.7.5	Discuss the impact of textile developments on improved athletic performance.	3	

D8 Transportation products

2 hours

	Assessment statement	Obj	Teacher's notes
D.8.1	Outline the use of smart and technical textile materials in vehicles.	2	For example, seatbelts, upholstery, airbags, knitted and coated fluid hoses, comfort sensors in vehicle seat textiles, hardwearing antistatic interior vehicle trims, flame-retardant heat shields in engine compartments, "triple fresh" vehicle carpets that decompose pollutants, and abrasion-resistant cable protection.
D.8.2	Discuss the advantages of the use of smart and technical textiles in vehicles compared to more traditional materials.	3	

D9 Markets

4 hours

	Assessment statement	Obj	Teacher's notes
D.9.1	Discuss the diversity of end-users of textile products.	3	Refer to agriculture, building and construction, aerospace, clothing, medical and military applications.
D.9.2	Outline the purpose of the information provided on textile labels.	2	
D.9.3	Discuss the impact of health and safety legislation governing textile product labelling.	3	
D.9.4	Describe how packaging materials and display methods affect the promotion of textile products.	2	
D.9.5	Discuss the impact of alternative packaging on product cost and the environment.	3	
D.9.6	Outline the positive and negative impacts of male and female modelling of textile garments on the behaviour and health of adolescents.	2	

	Assessment statement	Obj	Teacher's notes
D.9.7	Explain how shopping outlets code and mark their stock to help protect against theft.	3	
D.9.8	Explain the impact of the lack of international standardization of clothing labels on marketing strategies.	3	Consider mass production for a global market.
D.9.9	Define <i>brand</i> .	1	
D.9.10	Explain how the packaging of textile garments contributes to the development of brand loyalty.	3	
D.9.11	Discuss branding as a global marketing strategy.	3	
D.9.12	Discuss the positive and negative effects of product branding on adolescents.	3	
D.9.13	Discuss the global impact of branded textile products.	3	For example, Nike, Billabong or similar.

D10 Silk

3 hours

	Assessment statement	Obj	Teacher's notes
D.10.1	Describe the silkworm.	2	The silkworm is not a worm but a moth whose cocoon is made of silk. It is native to Northern China.
D.10.2	Outline the key stages in the life cycle of the silkworm.	2	The adult moth lays about 200–500 tiny yellow eggs, which turn black and eventually hatch into larvae. The larva eats mulberry leaves almost constantly for 4–6 weeks until it is about 3 inches long. It moults its skin many times as it grows. It then pupates into a brown pupa and spins a white silk cocoon around itself (a process taking about 3 days). After about 3 weeks the flightless adult moth emerges to reproduce, dying after about 5 days.
D.10.3	Describe the cocoon of the silkworm.	2	The cocoon comprises a single, continuous thread of silk. It is made of a protein that is secreted from two salivary glands in the head of the larva. The larva also secretes a sticky substance called sericin to bind the threads together.
D.10.4	Describe how silk fibres are harvested from silkworm cocoons.	2	The silkworm cocoon is put in boiling water to kill the pupa, to release the sericin from the outside and unravel the thread. Each cocoon contains a single silk thread that is 300–900 m long.
D.10.5	Explain why silk production using silkworms has remained a craft industry.	3	There has been no mechanization of the silk industry. This has led to a vast range of different designs with no standardization. The materials do not lend themselves to mechanization. The industry remains today a typical cottage industry.

	Assessment statement	Obj	Teacher's notes
D.10.6	Explain that silk production was kept a carefully guarded secret by the Chinese, who maintained a monopoly on silk production for about 3,000 years.	3	According to Chinese legend, the first silk thread was made when a Chinese Empress (Xi-Ling-Shi) was sitting under a mulberry tree and a cocoon fell into her tea. The strong, silky thread of the cocoon uncoiled. The Empress experimented with silkworms and developed silk weaving processes around 2400BC. Silk was very important to the Chinese economy and remained a Chinese secret for thousands of years, due in part to the Great Wall of China. Other peoples in central and western Asia learned how to spin and weave the threads supplied by the Chinese. In the 5th century, a Chinese princess married the king of Khotan (north of Tibet) and smuggled out silkworm cocoons and seeds of the mulberry tree. Similarly in the 6th century, Persian Christians visiting Khotan hid silkworm cocoons in their hollow walking sticks. Silk production gradually spread through western Asia and Europe. By the 15th century, France and Italy were the leading manufacturers of silk in Europe. In the 17th century, because of religious persecution, large groups of skilled Flemish and French weavers fled to England, and an industrial complex for silk weaving developed in London.
D.10.7	Describe the “Silk Road”.	2	The Chinese traded silk fabric to the rest of the world via the “Silk Road”, an overland trade network from China across the deserts of central Asia to Italy. It opened in about 100BC.
D.10.8	Explain why the “Silk Road” can be considered as the information superhighway of its day.	3	The major product traded from East to West was silk. However, the “Silk Road” involved many cultures. It served as the conduit for goods and also for the transmission of knowledge and ideas between East and West until the late 15th century when a sea route from Asia to Europe was discovered. The sea route was cheaper and safer than the land route.
D.10.9	Explain why silk substitutes, for example, nylon and rayon, marginalized but never replaced silk as a fibre.	3	The price of silk was very high; nylon and other silk substitutes were much cheaper but did not have the same material properties—absorbency, comfort. For some applications, nylon replaced silk, for example, stockings. However, silk products became even more specialized and, although they were marginalized, they were not replaced.
D.10.10	State that silk spiders also produce silk.	1	
D.10.11	Describe why silk spiders cannot be commercially reared like silkworms.	2	Silk spiders are aggressive and will attack and eat each other if kept in captivity. Thus commercial silk spider rearing is not an option.
D.10.12	Describe the characteristics of spider silk (“bio steel”).	2	Spider silk is five times as strong as steel and twice as strong as Kevlar®. It can stretch to 30% of its original length without breaking.

	Assessment statement	Obj	Teacher's notes
D.10.13	Explain how artificial spider silk is produced from goat's milk through genetic engineering.	3	Genetic material has been produced from the silk spider and injected into a goat's egg pre-fertilization by Canadian researchers. The spider gene is activated during lactation. About 5 g of silk proteins can be produced per litre of transgenic goat's milk, and a goat can produce about 1.5 litres of milk per day.
D.10.14	Describe why artificial spider silk protein cannot be spun into a fibre.	2	The spider's spinneret organizes the silk proteins and generates the required silk structure. This process cannot be replicated in the laboratory. Thus artificial spider silk production has been abandoned.

HL D11 Smart clothing and wearable computing

5 hours

	Assessment statement	Obj	Teacher's notes
D.11.1	Define <i>intelligent fabric</i> and <i>haptic technology</i> .	1	
D.11.2	Describe smart clothing.	2	Smart clothing is a combination of electronics and clothing textiles incorporating new fibre and textile materials and miniaturized electronic components. One smart clothing project developed a prototype suit for experienced snowmobile users to prevent accidents and help them to survive in the case of an accident. The suit integrated sensors monitoring the wearer's health, location and movements, and was able to inform an emergency office if necessary. Smart clothing can be designed for a range of applications, for example, medical. Heat can be transferred through conducting fibres to warmer or cooler parts of the body.
D.11.3	Describe wearable computing.	2	Wearable computing incorporates a small portable computer designed to be worn on the body during use (not hand-held like a PDA). Wearable computers are usually integrated into the user's clothing or can be attached to the body by other means, for example, a wristband.
D.11.4	Identify key areas of research required to promote wearable computing.	2	Consider user interface design; augmented reality; pattern recognition; specialist applications, for example, medical applications or disability; electronic textiles; fashion design; mass production techniques; power management; heat dissipation; software architecture; and wireless and personal area networks.

	Assessment statement	Obj	Teacher's notes
D.11.5	Identify the key challenges for wearable computing garments.	2	The interaction of devices with the body is complex and comfort is affected by weight distribution (static and dynamic), pressure on the skin and fit. Price is a key issue. In standard garments stretch is in-built so garments can accommodate a wider range of sizes. For wearables, the precise placement of components and their ongoing connection is critical. Wearables require a homogenized user. Wearable garments have only been successful where the problem of homogenization has been overcome, for example, for high-end luxury craft-produced items or where there is less anthropometric variation. Care and maintenance are key issues.
D.11.6	Identify alternative input and output devices for use with wearable computing.	2	Key issues for wearable computers relate to the input and output devices. Input devices: passive sensors, adapted keyboards, microphone, wireless Bluetooth. Output devices: head-mounted display, earphone, visual or audio augmented reality interface or haptic output device.
D.11.7	Identify the advantages and disadvantages of a range of input/output devices for wearable computing applications.	2	Consider portability, aesthetics, security, user-friendliness and training issues for the devices identified in D.11.6.
D.11.8	Describe an intelligent fabric.	2	Consider Elektex® fabric and its applications for the fabric controls in wearable computing garments. Elektex is a laminated textile comprising two conducting outer layers separated by a partially conducting central layer, which acts as an insulator when not pressed and as a conductor when pressed. The fabric is sensitive to different applied pressures. Advantages of Elektex include that it produces a smooth fabric finish, it is durable, flexible and can be hand-washed.
D.11.9	Explain how the design of wearable computing garments brings together multidisciplinary teams.	3	
D.11.10	Compare the markets for fashion garments and consumer electronics and the implications for wearable computing garments.	3	The fashion market targets customers very specifically. The consumer electronics market is not so specific. This poses enormous challenges for wearable computing garments. Wearable computing has been more successful when designed and sold for a particular application, for example, portable MP3 players and cell phones with wireless microphone attachments. The psychology of fashion and its implications for wearable computing garments need to be taken into account. Wearable computing garments must be marketed in a lifestyle way to access wider markets. The criteria for clothing purchases are aesthetics, ethics, protection, value and accessibility.

	Assessment statement	Obj	Teacher's notes
D.11.11	Discuss how technology push and market pull impact on the wearable computing market.	3	
D.11.12	Identify obstacles to the expansion of the wearables market.	2	Price, need, fashion, health and safety, and lack of distinction from other high-tech products.
D.11.13	Discuss the benefits of aligning the wearable computing market more closely with the fashion market.	3	Wearable technologies, for example, intelligent fabrics for controls and interface electronics, need to be made more accessible to mass clothing manufacturers. The time needed to develop new products needs to be reduced. The cost of wearable technology garments needs to be reduced. The products must be attractive to users. There needs to be a focus on products that deliver specific benefits.
D.11.14	Discuss the benefits of laser welding as a joining technique for the manufacture of wearable computing garments.	3	The manufacture of garments with added functionality requires viable joining techniques for fabric and connectors. There is conflict between micro-joining of electronics and macro-joining used for clothing. Stitching is the most common joining method for clothing manufacture but is labour-intensive, which is cost-prohibitive in most parts of the world, and it makes holes in the fabric, which disrupts the worn connectors, impairs the strength of the garment and reduces the performance of the seam. Advantages of laser welding include the ease of automation, high performance, the appearance and that the seams are effectively sealed.
D.11.15	Explain the potential contribution of the automation of manufacture of wearable computing garments.	3	There are implications of labour costs associated with manufacturing on the price of the finished garment and on the geographical location of manufacturing plants. Automation offers the opportunity to reduce local labour costs and to make garment manufacturing more viable across the world.
D.11.16	Evaluate a range of wearable computing garments.	3	Wearable computing garments on the market include O'Neill backpacks, Spyder jackets and iShirts. The wearable computing market is likely to be fast moving so consideration of current products is essential.

HL D12 Sustainability in the textile industry

5 hours

	Assessment statement	Obj	Teacher's notes
D.12.1	Discuss the impact of the introduction of mechanization in the textile industry on the workforce.	3	Refer to change from rural to urban locations; child labour; lack of health and safety regulations; poor working and living conditions; and unhealthy environments.
D.12.2	Explain the changes in working conditions that have occurred with the introduction of automation in the textile industry.	3	Refer to quieter machinery, healthier environment, and health and safety regulations.

	Assessment statement	Obj	Teacher's notes
D.12.3	Discuss sustainability issues in relation to the use of natural fibres.	3	Refer to cotton and wool.
D.12.4	Describe the links between global communication systems and the growth of multinational textile companies.	2	Consider the flow of raw materials, distribution networks for finished goods, and offices and factories in different global locations.
D.12.5	Outline the advantages and disadvantages of multinational textile companies establishing manufacturing outlets in developing countries.	2	Refer to overheads, capital costs, labour costs, infrastructure links and legislation.
D.12.6	Discuss the advantages and disadvantages for developing countries when large multinational companies establish textile manufacturing plants in their country.	3	Refer to employment, culture, politics, education and exploitation.
D.12.7	Outline the effects of import and export quotas (fair trade regulations) on the commercial development of the textile industry.	2	Consider developed and developing countries, trade agreements and disputes.
D.12.8	Discuss corporate social responsibility and "triple bottom line" (social, economic and environmental) sustainability of a rapidly growing and developing textile industry.	3	Refer to the conflict between wealth creation and market forces with social and moral responsibilities.
D.12.9	Discuss how the development of new textile technologies needs careful and considered implementation with regard to recycling, disposal and general use.	3	Refer to raw materials, finishing processes, energy use, feasibility of recycling and reuse.
D.12.10	Describe how different cultures influence textile design.	2	Consider history, local and national influences, and the media.

HL D13 Cotton and the "EU Flower": case study of an ecolabel

5 hours

	Assessment statement	Obj	Teacher's notes
D.13.1	Describe the significance of the "EU Flower" as an environmental quality mark covering a range of product categories.	2	The "EU Flower" is a symbol of superior environmental quality and is available for a range of products and services. The scheme sets out specific ecological criteria that products must comply with to be certified as environmentally friendly. The award of the label is independently verified and endorsed by the European Union (EU). The "EU Flower" is a recognized environmental quality mark across the countries of the EU and in Norway and Liechtenstein.

	Assessment statement	Obj	Teacher's notes
D.13.2	Outline the key benefits of the “EU Flower” system.	2	<p>Legal compliance: Integrated Product Policy (IPP)—life cycle assessment is a key step in assessing a product for the “EU Flower”. The EU uses greener standards and environmental taxes to force producers to take account of the environmental impact of their products. Products with the “EU Flower” will have been assessed for such impacts and will usually comply with these schemes.</p> <p>Opening new markets: The “EU Flower” is recognized across the EU and has been shown to help sales in other EU markets.</p> <p>Reducing costs: Cleaner production is required to meet the “EU Flower” criteria. This can be cheaper and more efficient, and also prevents potential costs associated with waste and pollution.</p> <p>Preferred supplier: There is a demand for environmentally friendly products among consumers and retailers. As a symbol of environmental quality, the “EU Flower” could help a manufacturer become a preferred supplier, particularly in the government sector.</p> <p>Eliminates confusion: Confusion about the overall impact of the product is eliminated. The whole life cycle is assessed, so consumers are confident that the product is environmentally superior from cradle to grave.</p> <p>Confidence: The “EU Flower” is independently verified. Environmental claims are endorsed and verified by the EU.</p> <p>Trustworthy: It is an EU scheme and research shows that the EU is one of the most trusted sources of environmental information.</p>
D.13.3	Explain how manufacturers would achieve the “EU Flower” label for their products.	3	<ol style="list-style-type: none"> 1. Check to see if the product has a published EU Ecolabel. 2. Undertake a product life cycle assessment focusing on the criteria set for each product by the EU Commission. 3. Supply test data to the designated National Standards Authority. 4. The designated National Standards Authority notifies the EU Commission of compliance with the criteria. 5. EU Commission publishes the award across the EU. 6. The “EU Flower” symbol is displayed on the product along with written information outlining the product’s environmental benefits.
D.13.4	Identify the range of textile products covered by the “EU Flower” label textiles product category.	2	The “EU Flower” can be awarded to all kinds of textile clothing and accessories, interior textiles, and fibres, yarn and fabric.

	Assessment statement	Obj	Teacher's notes
D.13.5	List the key benefits of the “EU Flower” system in limiting the environmental impact of a textile product at all stages of its life cycle from manufacture through use to disposal.	1	The “EU Flower”: <ul style="list-style-type: none"> • limits the use of substances harmful to the environment • limits the use of substances harmful to health, for example, through allergic reactions • reduces water and air pollution • requires textile shrink resistance during washing and drying • requires colour resistance to perspiration, washing, wet and dry rubbing and light exposure.
D.13.6	Discuss the key environmental issues involved in the cultivation of cotton products.	3	This stage in the production cycle has a massive potential effect on the environment. Use of pesticides is an issue in cotton cultivation.
D.13.7	Discuss the key environmental issues involved in the ginning process.	3	After harvesting, the fibres and seeds are separated in a process called ginning. The seeds are either sown the following year or converted into oil and feedstuffs.
D.13.8	Discuss the key environmental issues involved in spinning, knitting and weaving of cotton fibres.	3	Separating and washing cotton fibre and spinning it into yarn by traditional methods is noisy and dusty. So is the knitting or weaving of the yarn into fabrics. Cleaner technologies can be used to reduce these problems.
D.13.9	Discuss the key environmental impacts associated with the dyeing and printing of cotton and how these might be minimized.	3	Dyeing and printing of cotton fabrics can have a major environmental impact, especially on aquatic ecosystems. Many dyes are highly toxic, and waste wash water from cotton manufacture must be carefully treated. Refer to the pollution of waterways and groundwater.
D.13.10	Discuss the key environmental issues involved in cutting cotton fabrics and how these might be minimized.	3	Cutting processes can unnecessarily waste natural resources. It is important to arrange cutting and sewing to optimize use of the cloth.
D.13.11	Discuss the implications of the care and maintenance of textile products in the home on health and the environment.	3	Consider the use of detergents; synthetic fabrics and skin conditions; textile products as dust traps (carpets, curtains, upholstery); and the increase in asthma symptoms in children.
D.13.12	Discuss the key environmental issues involved in the reuse and recycling of cotton products.	3	Durability is a key issue for the life span of the textile product. Textile products, for example, clothing, can be passed on and, when finally worn out, recycled in other products.

Option E: Human factors design (30/45 hours)

“Human factors” and “ergonomics” are interchangeable terms—the term “human factors” is more commonly used in some parts of the world, such as the United States (US), and the term “ergonomics” is more widely used in other countries. Human factors analyses the interactions between humans and other elements in a system, and then applies principles, information and data to a design to maximize human well-being and system performance. Human factors design ensures that products, organizations, environments and systems are compatible with the needs and limitations of people. This can help to reduce the stress on people, as they will be able to do things faster, more easily, more safely and make fewer mistakes. This option builds upon knowledge gained from studying sub-topic 6.1, “Ergonomics”.

Core material: E1–E7 are core material for SL and HL (30 hours).

Extension material: E8–E11 are extension material for HL only (15 hours).

E1 Human factors design

3 hours

	Assessment statement	Obj	Teacher's notes
E.1.1	Identify the objectives of human factors design.	2	Consider effectiveness (completeness and accuracy), efficiency (speed and effort), engagement (pleasantness and satisfaction), error tolerance (error prevention and error recovery) and learnability (predictability and consistency) with which activities can be carried out and how human values, for example, quality of life, improved safety, reduced fatigue and stress, increased comfort levels and job satisfaction, are enhanced.
E.1.2	Describe why visibility is an important consideration in human factors design.	2	Controls should be visible and it should be obvious how they work. They should convey the correct message, for example, with doors that need to be pushed, the designer must provide signals that indicate where to push.
E.1.3	Describe why feedback is an important consideration in human factors design.	2	Feedback is the provision of information, for example, an audible tone to a user, as a result of an action. The tone on a telephone touchpad or the click of a key on a computer keyboard provides feedback to indicate that a key has been pressed. The “egg timer” icon on a computer screen tells the user that an action is being undertaken.
E.1.4	Describe why mapping is an important consideration in human factors design.	2	Mapping relates to the correspondence between the layout of the controls and their required action. For example, the layout of the controls on a cooker hob can take advantage of physical analogies and cultural standards to facilitate a user's understanding of how it works.

	Assessment statement	Obj	Teacher's notes
E.1.5	Describe why affordance is an important consideration in human factors design.	2	Affordance is the property of an object that indicates how it can be used. Buttons afford pushing, and knobs afford turning. On a door, handles afford pulling, whereas push plates afford pushing. Consider how the use of a handle on a door that needs to be pushed open can confuse users, and how in an emergency this might impact on safety considerations.
E.1.6	Describe why constraints are an important consideration in human factors design.	2	Constraints limit the way that a product can be used. The design of a three-pin plug or a USB (universal serial bus) device ensures that they are inserted the correct way. This reduces or eliminates the possibility of a user making errors.
E.1.7	Explain why consumers misuse many products due to inappropriate human factors considerations in their design.	3	It is not always obvious from looking at products how they should be used. Consider visibility, feedback, mapping, affordance and constraints.
E.1.8	Explain why the aims of human factors may conflict with other design aims.	3	Examine the notion of optimum compromise and consider cost, form, function, which may be more important aims to achieve in a specific design context.
E.1.9	Explain that the ergonomic data required in systems design depends on the role of people in that system.	3	Consider an operator of a system or a user of a system. Reduced system efficiency and failures that occur early in the life cycle are frequently caused by poor human factors design.

E2 Human factors data

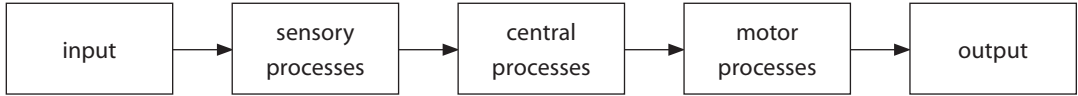
4 hours

	Assessment statement	Obj	Teacher's notes
E.2.1	Define <i>user population</i> .	1	
E.2.2	Outline how large user groups may be defined.	2	Consider age, gender and physical condition.
E.2.3	Outline the importance of sampling to gain information about potential users.	2	When considering a product designed for mass use, it is not good to rely on information collected from just a few people, as it is unlikely to be representative of the whole range of users.
E.2.4	Describe how a user group sample is based on the factors considered in E.2.2.	2	
E.2.5	Discuss how the factors in E.2.2 are further defined to determine the exact nature of a user group sample.	3	The factors in E.2.2 are all characteristics that are important to the evaluation. These characteristics are the ones that must be represented by the members of the sample.
E.2.6	Outline the use of the concept of "methods of extremes" to limit sample sizes.	2	Sample users are selected to represent the extremes of the user population plus one or two intermediate values, for example, evaluating a kitchen layout may use the shortest (2.5th percentile), the mean (50th percentile) and the tallest (97.5th percentile).
E.2.7	Define <i>population stereotypes</i> .	1	

	Assessment statement	Obj	Teacher's notes
E.2.8	Describe the relevance of the use of population stereotypes in the design of controls for products.	2	It is usually anticlockwise for "on" when dealing with fluids and gases, for example, a tap, and clockwise for "on" when dealing with mechanical products, for example, a radio.
E.2.9	Discuss the problems of displacing population stereotypes in the design of controls for products.	3	Population stereotypes can be displaced by alternative learnt responses, but they frequently reassert themselves under conditions of stress such as tiredness or panic.
E.2.10	Discuss how the use of converging technology in product design may lead to confusing control layout.	3	For example, gas cooker controls are turned clockwise for "off", but for an electric cooker they are the other way round. This is because the gas cooker knobs are effectively taps, operating a fluid or gas. This can be confusing for consumers and can be a safety hazard, especially with a gas hob and electric oven combined into one product.
E.2.11	Discuss how the concepts of "range of sizes" and "adjustability" affect the design of products.	3	Consider clothing, cars, furniture and the ironing board.
E.2.12	Compare the collection of static anthropometric data with the collection of dynamic anthropometric data.	3	Static data is much easier to gather, as people are asked to remain still while measurements are taken. Dynamic data involves people carrying out tasks. People carry out tasks in many different ways. While static data is more reliable, dynamic data is often more useful.
E.2.13	Describe the instruments used in the collection of anthropometric data.	2	For example, sliding calliper, stadiometer, sitting height table, cloth tapes, torso callipers, and Harpenden anthropometer.
E.2.14	Explain why it is difficult to obtain accurate anthropometric data using the equipment described in E.2.13.	3	Refer to obtaining data from nude and clothed people.
E.2.15	Identify an appropriate percentile range for the design of adjustable equipment.	2	Equipment might include car seats, office chairs, desk heights, footrests. The range from 5th percentile female to 95th percentile male will accommodate 95% of a male and female population because of the overlap between female and male body dimensions for each dimension. Multivariate accommodation (fitting in several variables, for example, in a car you need to fit in terms of sitting height, leg room, arm reach, viewing angles, hip breadth, thigh length) means that accepting 5% being designed out for each important dimension is not viable, because different people will be designed out for each variable. People have different proportions. Those designed out because they are too tall may not be the same as those designed out because their arm reach is too short.
E.2.16	Explain how designers use primary and secondary anthropometric data in solving a design problem.	3	
E.2.17	Define <i>biomechanics</i> .	1	
E.2.18	Discuss the importance of biomechanics to the design of a given artifact.	3	Consider muscle strength, age, handle size, surface texture, and torque (for example, in a can opener, valve wheel, corkscrew, door handle, jam jar lid).

E3 Research and testing

3 hours

	Assessment statement	Obj	Teacher's notes
E.3.1	List four types of data scales.	1	List nominal, ordinal, interval and ratio data scales.
E.3.2	Describe nominal scale.	2	This scale only classifies objects into discrete categories, for example, food groups. Nominal means "by name" and labels are used for the categories of objects. Nominal scales are very weak, as they do not tell you anything more than that one object is different from another.
E.3.3	Describe ordinal scale.	2	As with nominal scales, the labels used in ordinal scales can be words, symbols, letters or numerals. When numerals are used, they only indicate sequence or order, for example, ranking someone by placing them in a competition as "third" rather than by a score—they may have come third with 50% right or with 75%.
E.3.4	Describe interval scale.	2	An interval scale is a more powerful scale, as the intervals or difference between the points or units are of an equal size, for example, in a temperature scale. Measurements using an interval scale can be subjected to numerical or quantitative analysis.
E.3.5	Describe a ratio scale.	2	The difference between a ratio scale and an interval scale is that the zero point on an interval scale is some arbitrarily agreed value, whereas on a ratio scale it is a true zero. For example, 0°C has been defined arbitrarily as the freezing temperature of water, whereas 0 grams is a true zero, that is, no mass.
E.3.6	Explain the relevance of using the different rating scales to design contexts.	3	For example, a comfort rating scale of 1–10 is an ordinal scale.
E.3.7	Describe the human information-processing system.	2	For example, a car driver processes information from the road and the car, and produces various control responses such as braking or changing gear.
E.3.8	Explain that the human information-processing system can be represented by an information flow diagram.	3	The arrows represent the flow of information through the system. The boxes represent functional elements in the processing chain, where information is processed.
 <pre> graph LR input --> sensory[sensory processes] sensory --> central[central processes] central --> motor[motor processes] motor --> output </pre>			
E.3.9	Apply the information flow diagram to particular contexts.	2	For example, when using a mobile phone to make a telephone call. The input would be the number to be called. The sensory processes would be the eyes, which would transmit information to the brain. The brain is the central processing unit, which examines the information and selects a response coded as a series of nerve impulses transmitted to the hand and muscles. These are the motor processes, which reconvert the instructions into actions, that is, outputs.

	Assessment statement	Obj	Teacher's notes
E.3.10	Outline how the flow process described in E.3.9 may break down.	2	The information inputs may be incompatible with the sensory receptors. At the central processing stage, the incoming information may be incorrect or no suitable responses to it are available. The motor output stage may be unable to perform the actions specified by the central processing unit.
E.3.11	Outline how motor outputs may be inhibited if the physical fit between the person and the environment is wrong.	2	Consider problems encountered by young children and elderly, infirm or disabled people.

E4 Modelling

3 hours

	Assessment statement	Obj	Teacher's notes
E.4.1	Define <i>manikin</i> , <i>ergonome</i> , <i>appearance prototype</i> and <i>functional prototype</i> .	1	
E.4.2	Outline the use of ergonomes to represent human factors data.	2	Ergonomes are used with 2D drawings, mainly orthographic drawings.
E.4.3	Discuss advantages and disadvantages of the use of ergonomes to represent human factors data.	3	Ergonomes only give an approximate idea of the relationship between sizes of body parts and sizes of objects, for example, reach. However, they are cheap and easy to use.
E.4.4	Outline the use of manikins to represent human factors data.	2	Manikins are useful for assessing the relationship of body parts to spatial arrangements represented by a 3D model, for example, a chair to a desk.
E.4.5	Discuss advantages and disadvantages of the use of manikins to represent human factors data.	3	Manikins are more expensive and time-consuming than ergonomes because of the need for 3D models but are more realistic representations of a design context.
E.4.6	Outline the use of appearance prototypes to gain human factors data.	2	Appearance prototypes look like but do not work like the final product. Appearance prototypes can be relatively simple, consisting of solid chunks of foam finished and painted to look like the real thing, or they can be more sophisticated, simulating weight, balance and material properties. Usually, appearance prototypes are "for show" and are not designed to be handled excessively.
E.4.7	Outline the use of appearance prototypes at the design development stage.	2	They give non-designers a good representation of what the object will look like and feel like. For example, marketing directors can make judgments and production engineers can take data for assessing feasibility for matching manufacturing systems. They are expensive to produce, as they need to have a good surface finish and be life-size.
E.4.8	Outline the use of a functional prototype model to evaluate human factors aspects of a design.	2	It allows for more interaction with potential users, for example, a range of percentile groups. Also bodily tolerances can be measured.

	Assessment statement	Obj	Teacher's notes
E.4.9	Discuss the advantages of the use of functional prototypes for gaining human factors data.	3	
E.4.10	Identify design contexts in which clay, card and polymorph may be used for human factors modelling.	2	Polymorph is a new generation of non-hazardous, biodegradable polymer, which can be used repeatedly for modelling. It is supplied as granules, which are poured into hot water to make a soft, pliable material. On removal from the water, the material can be moulded into the desired shape. On cooling, it becomes a tough machinable engineering material.

E5 Health and safety legislation

3 hours

	Assessment statement	Obj	Teacher's notes
E.5.1	Describe the objectives of product safety testing.	2	<p>The objectives of product safety testing are to reduce accidents and improve the safety and physical well-being of people through:</p> <ul style="list-style-type: none"> • verification that a product is safe for intended and unintended uses • verification that a product meets or exceeds the requirements of all safety regulations • identification of any unforeseen ways that the product may be misused.
E.5.2	Identify the general human factors contributing to accidents.	2	Categories of factors that cause accidents include management (policies, safety education, decision centralization), physical environment (noise, temperature, pollutants, trip hazards, signage), equipment design (controls, visibility, hazards, warnings, guards), the work itself (boredom and repetitiveness, mental and physical workload, musculoskeletal impacts such as force, pressure and repetition), social and psychological environment (group norms, morale), and the worker (ability, alertness, age, fatigue).
E.5.3	Outline the factors that contribute to thermal comfort in office and other working environments.	2	Thermal comfort describes a person's psychological state of mind and involves a range of environmental factors: air temperature, the heat radiating from the Sun, fires and other heat sources, air velocity (still air makes people feel stuffy, moving air increases heat loss), humidity, and personal factors (clothing and metabolic rate). Hopefully in an office environment where a number of people work together, the thermal environment satisfies the majority of the people. Thermal comfort is not measured by air temperature, but by the number of people complaining of thermal discomfort. Thermal comfort affects morale and productivity.

	Assessment statement	Obj	Teacher's notes
E.5.4	Discuss the legislative requirements for temperature in the workplace.	3	Legislation sets minimum and maximum temperatures for different types of workplace, and workers have the right to refuse to work if such temperatures are not maintained.
E.5.5	Outline the legislative requirements for decibel levels for working with machinery.	2	Excessive noise in the workplace can cause workers to lose their hearing and/or to suffer from tinnitus (permanent ringing in the ears). The level at which employers must provide hearing protection and hearing protection zones in, for example, the UK is now 85 decibels (daily or weekly average exposure), and the level at which employers must assess the risk to workers' health and provide them with information and training is now 80 decibels. There is also an exposure limit value of 87 decibels, taking account of any reduction in exposure provided by hearing protection, above which workers must not be exposed.
E.5.6	Discuss the legislative incentives to incorporate human factors into product design.	3	Consider safety standards and regulations that must be followed, but also methods of avoiding future litigation against failed products. Such methods include: <ul style="list-style-type: none"> • always include a "duty to warn" • design safety into the product • incorporate a greater safety factor than that required by legislation • analyse all consequences of product use and misuse • rigorously test one or more prototypes in a realistic context before finalizing the design.
E.5.7	Describe the methods used for identifying hazards and evaluating risks.	2	Methods include the following. Scenario analysis attempts to identify patterns of behaviour that precede accidents. If such behaviour can be identified, then it may be avoided by a redesign of a product. Fault tree analysis determines the causes of failures by first identifying the types of injuries that may occur and concluding with redesign solutions. Hazard assessment determines probable causes for injury and indicates ways to eliminate the hazards.
E.5.8	Explain how human factors specialists determine adequate product safety.	3	Behavioural testing: perform some activity with the product such as unpacking, assembly, operation and maintenance. Conceptual testing: evaluate safety instructions and warning messages without exposing people to hazardous conditions.

E6 Design for usability

2 hours

	Assessment statement	Obj	Teacher's notes
E.6.1	Identify three characteristics of good user–product interfaces.	2	The user–product interfaces of many electronic products are extremely complex rather than being intuitive and easy to use. Products with intuitive and easily accessible interfaces are likely to be more popular with consumers (especially more affluent and older consumers). Three important characteristics are: simplicity and ease of use; intuitive logic and organization; and low memory burden. Consider which product features are essential or likely to be used with greatest frequency; the functionality required by a typical user; and the common learning problems encountered by users.
E.6.2	Explain the disadvantages of user–product interfaces that are not well organized and cannot be learnt intuitively and remembered easily.	3	Novice users of a product should be able to learn all its basic functions within one or two hours. However, many products are full of confusing detail and are difficult to learn. This can lead to incomplete use of the product's functionality and frustration for the user. Instruction manuals are often poorly written and poorly organized.
E.6.3	Discuss the impact of memory burden on the user-friendliness of a product.	3	Poor organization of a product imposes a memory burden on users, who have to learn and remember how the various functions work. This results in them not using the full functionality of a product but focusing on a limited set of features and ignoring those that are difficult to remember. Thinking about how intuitively the product features can be accessed by users can reduce memory burden and make the product more user-friendly.
E.6.4	Explain why it is difficult for designers to develop simple intuitive user–product interfaces.	3	It is difficult for the designer of a product to distance him/herself from the product and look at it through the eyes of the prospective user. Reinnovation of a product often involves adding features to the basic design rather than redesigning the user–product interface from scratch, and this can result in a disorganized interface. It is important to consider necessary and desirable features, not ones that increase complexity without enhancing usefulness for most users.
E.6.5	Define <i>paper prototyping</i> .	1	
E.6.6	Explain that paper prototyping is one example of participatory design.	3	Paper prototyping is sometimes called low-fidelity prototyping. It is one example of participatory design, that is, it involves users in design development.

	Assessment statement	Obj	Teacher's notes
E.6.7	Explain the roles of the facilitator, the user, the computer and the observer in a paper prototyping session.	3	Facilitator: explains the purpose of the session to the user and how to interact with the prototype. User: represents the target market for the product, and interacts with the user-product interface to "use" the product in response to guidance from the facilitator. Computer: a human being simulating the behaviour of the computer program in response to instructions from the user. Observer: watches what happens and can ask more questions of the user.
E.6.8	Explain the advantages of paper prototyping.	3	It is cheap and easy to implement. A paper prototype can be quickly and easily modified and retested in the light of feedback from representative users, so designs can be developed more quickly. It promotes communication between members of the development team. No computer programming is required, so paper prototyping is platform-independent and does not require technical skills. A multidisciplinary design team can collaborate on design development.

E7 Contexts

12 hours

	Assessment statement	Obj	Teacher's notes
Product: mobile phone (3 hours)			
E.7.1	Outline three elements of anthropometric data used in the design of a mobile phone.	2	For example, finger dimensions, hand size, thumb width, viewing angle.
E.7.2	Outline one design factor related to ease of use of the mobile phone that has compromised the use of human factors data.	2	For example, miniaturization of components and portability.
E.7.3	Outline psychological human factors data that could be used in the design of a mobile phone.	2	For example, texture, sound, colour and light.
E.7.4	Discuss the relationship between fashion and human factors in the design of the mobile phone.	3	Fashion relates to style, for example, chunky or ultra-slim, and texture, which then have an impact on ease of use, portability.
E.7.5	Define <i>aesthetic-usability effect</i> .	1	
E.7.6	Discuss how the aesthetics of a mobile phone make it look easier to use and increase the probability of it being used, whether or not it is actually easier to use.	3	Consider point-of-sale impact and recommendations of other users even though they have different human factors requirements.

	Assessment statement	Obj	Teacher's notes
System: kitchen (3 hours)			
E.7.7	Describe the concept of a work triangle in relation to kitchen layout.	2	A work triangle is used to assess the efficiency of placing key appliances in a design, for example, fridge, cooker and sink.
E.7.8	Explain the principles of the work triangle in relation to safety issues in a kitchen.	3	Consider transport of hot food, and carrying heavy objects.
E.7.9	Discuss the “sequence of use” design principle as applied to kitchen design.	3	The sequence of use for a right-handed person is from left to right, from the sink to the main work surface to the cooker and to accessory work surfaces.
E.7.10	Outline three examples of the use of anthropometric data in kitchen design.	2	For example, height of work surfaces, position of cupboards, depth of worktops, circulation space.
E.7.11	Outline psychological human factors data that could be used in kitchen design.	2	For example, perception of texture, temperature, light and colour.
E.7.12	Discuss the differences in human factors data that may be relevant for a domestic kitchen compared to a commercial restaurant kitchen.	3	Consider the interaction of the staff involved, heat generated, ventilation, access areas, storage, and health and safety issues.
E.7.13	Discuss how the layout of labelling information for kitchen appliances can be misleading to the user.	3	For example, microwave ovens often have different labelling for control panels.
E.7.14	Outline physiological human factors data that could be used when designing kitchen products.	2	For example, viewing distances, pulling strength, lifting strength and turning strength.
Environment: open-plan office (3 hours)			
E.7.15	Outline the influence of the psychological human factors of noise and temperature on the design of an open-plan office.	2	Consider sound-absorbing acoustic partitions, separate noisy equipment, silent phone tones, ventilation flow, static and dynamic tasks.
E.7.16	Discuss how the final design of an open-plan office is a compromise between individual space preferences and standardized design.	3	Space is often allocated based on standardized tasks or office status, but different individuals have different personal space needs.
E.7.17	Discuss safety considerations that impact on the design of an open-plan office.	3	For example, cable layout and other tripping hazards, people circulation spaces, storage areas, and fire evacuation plans.
E.7.18	Identify psychological and physiological factors that influence the design of office furniture.	2	Consider comfort, adjustability, long periods of use and aesthetics.
E.7.19	Outline three examples of the use of anthropometric data in the design of office furniture.	2	

	Assessment statement	Obj	Teacher's notes
Environment: car (3 hours)			
E.7.20	Outline how the location and layout of car controls influence efficient use.	2	For example, car window controls on the door make it a better design than that of window controls in the centre console.
E.7.21	Discuss how designers have used new technology to redesign the interiors of cars to improve human factors issues.	3	For example, the use of colours, sound and voice synthesizers to warn the driver of different situations.
E.7.22	Discuss how designers have redesigned the interiors of cars to the benefit of passengers and drivers.	3	For example, climate control, zoned heating and memory adjusting seats.
E.7.23	Discuss how designers may overlook the implications for human factors when designing multifunctional electronic controls in cars.	3	As with other electronic appliances, designers can overstep the mark by allowing technology to dictate the design. Many users find multifunctional electronic controls a problem, either because they do not understand them or because the controls are physically too difficult to use.

HL E8 Digital humans

3 hours

	Assessment statement	Obj	Teacher's notes
E.8.1	Define <i>digital human</i> and <i>motion capture</i> .	1	
E.8.2	Explain how motion capture is used to digitally represent motion.	3	A person wears a set of acoustic, inertial, LED, magnetic or reflective markers at each joint. Sensors track the position of the markers as the person moves to develop a digital representation of the motion.
E.8.3	Identify the advantages of motion capture for digitally representing motion.	2	Motion capture can reduce the cost of animation, which otherwise requires the animator to draw either each frame or key frames that are then interpolated. Motion capture saves time and creates more natural movements than manual animation, but is limited to motions that are anatomically possible. Some applications, for example, animated super-hero martial arts, might require additional impossible movements.
E.8.4	Explain how motion capture contributes to the development of a digital human.	3	A motion capture session records the movements of the actor, not his or her visual appearance. The captured movements are mapped to a 3D model (human, giant robot) created by a computer artist, to move the model in the same way.
E.8.5	Discuss how digital humans can enhance human factors research.	3	Digital humans can be used to represent joint resistance, discomfort, reach envelopes and visual fields. They can be used, for example, to measure the impact of clothing on human performance.

	Assessment statement	Obj	Teacher's notes
E.8.6	Explain how digital humans enable the consideration of human factors early in the design cycle.	3	<p>Using digital humans early in the design of a vehicle for example, before a physical prototype is built:</p> <ul style="list-style-type: none"> • allows the design to be optimized for user comfort, visibility and access to controls • ensures that people of different sizes will be able to see when they operate the vehicle • ensures that the user population will be able to climb in and out of the vehicle easily • ensures that the controls and foot pedals are within the reach of and can be operated by users • ensures that the vehicle can be maintained • ensures that the strength required to operate the vehicle is within the normal range.
E.8.7	Explain how digital humans can increase the speed of the product development cycle.	3	<p>Human simulation in product design enables a product to be developed more quickly, as there can be more design iterations in less time. This results in higher product quality, which meets human requirements more accurately. Digital prototypes are cheaper to produce than physical prototypes. Products are safer as a result of more thorough analysis of safety aspects. Improved productivity results from enhanced automation of the development process.</p>
E.8.8	Explain the benefits of using digital humans in developing manufacturing plants and processes, maintenance and training.	3	<p>Digital humans enable manufacturing plants to be developed more quickly and manual workflow to be optimized. They improve worker safety and reduce compensation costs resulting from accidents. Machines and other equipment can be positioned to optimize cycle time and avoid hazards. Manufacturing processes can be designed to eliminate inefficiencies and ensure optimal productivity. They can be used to: ensure that people can access the parts and equipment needed to assemble products; check that workers can effectively use any hand tools needed to perform manual tasks; and check that all tasks can be performed safely without requiring inordinate strength or exposing people to risk of injury.</p> <p>Using digital humans enables designers to ensure that there is sufficient space to perform maintenance tasks, including space for hands, arms and tools, and space to install and remove parts. Designers can check that technicians can see when they do specific maintenance tasks and that they can use the requisite hand tools.</p> <p>Digital humans enable people to be trained in multiple locations without the need for physical prototypes or actual equipment and so reduce the cost of training manufacturing and maintenance personnel.</p>
E.8.9	Explain the advantages of using digital humans in product marketing.	3	<p>Digital humans can be used in e-commerce to model clothing products. A customer can produce a model corresponding to his or her body shape, size and look. The model can then try on clothing so that the customer can see what it might look like, for example, www.landsend.com.</p>

HL E9 Design for disability**6 hours**

	Assessment statement	Obj	Teacher's notes
Wheelchair-related design (2 hours)			
E.9.1	Identify human factors issues related to wheelchair design.	2	Consider the range of anthropometric dimensions, posture, comfort and pressure management.
E.9.2	Explain the methods that designers would use to research human factors for wheelchair design.	3	Consider user research methods related to wheelchair users and carers. Research into existing products, systems and environments for modification to allow use by wheelchair users.
E.9.3	Identify ways in which a consideration of human factors would improve the design of wheelchairs.	2	Consider strength, grip, circulation space, storage, weight, reach, safety, comfort and fatigue.
E.9.4	Discuss the role of legislation in ensuring wheelchair access in public buildings.	3	Consider the problems of adapting existing designs compared to new builds.
E.9.5	Evaluate the requirements for wheelchair access in the school environment.	3	
Design for limited hand movement (2 hours)			
E.9.6	Identify human factors issues for those with limited hand movement.	2	
E.9.7	Explain the methods that designers would use to research human factors for those with limited hand movement.	3	
E.9.8	Identify kitchen appliances that could be modified for greater ease of use for people with limited hand movements.	2	Consider anthropometric data and range of movement.
E.9.9	Explain suitable modifications to the kitchen appliances identified in E.9.8 to enhance ease of use for people with limited hand movements.	3	
E.9.10	Outline the forces involved in unscrewing the lid of a jar.	2	Consider torque and grip.
E.9.11	Describe a range of products designed to assist people to unscrew the lid of a jar.	2	
Design for disability in a global society (2 hours)			
E.9.12	Discuss the issues of human factors research in developing and developed countries.	3	In developing countries, disability issues are often not covered by legislation or deemed a priority. Compare this with the position in developed countries.
E.9.13	Explain the social responsibility of designers to design for all impaired groups.	3	Design attempts to improve the life of people. New technology allows for increased individuality in the design of products to meet the needs of consumers of all types.

	Assessment statement	Obj	Teacher's notes
E.9.14	Discuss the role of legislation in ensuring inclusive design for community facilities.	3	Consider legislation through standards, design incentives and regulations.
E.9.15	Identify the opportunities presented by the global marketplace for design for specific impairments.	2	Disability groups are often referred to as minority user groups who do not benefit from economies of scale. Hence products for them are much more expensive than comparable products for other user groups. However, on a global scale, disability groups represent major markets and deserve to be treated accordingly.
E.9.16	Describe the benefits of increased access to product information by impaired consumers.	2	The Internet offers individual users as well as organized groups the opportunity to carry out research into and gain access to products that would not be possible by more conventional means.

HL E10 Design for purpose

4 hours

	Assessment statement	Obj	Teacher's notes
Design for discomfort (1 hour)			
E.10.1	Identify design contexts that have been purposely designed to provide only basic comfort for short periods of time.	2	Consider a fast-food restaurant and an airport.
E.10.2	Explain considerations that may conflict with human factors in the seating design for a fast-food restaurant and an airport.	3	For example, consider airport seating that has to be used during lengthy flight delays, or families who use a fast-food restaurant for a meal event rather than just for a fast snack.
E.10.3	Identify ways in which designers reconcile conflicting design considerations.	2	For example, public seating in railway stations needs to be robust, easy to maintain, look good, resist vandalism and be relatively cheap.
Signage (1.5 hours)			
E.10.4	Discuss the importance of international standards in airport signage.	3	Information via the use of graphics rather than words.
E.10.5	Identify the shape and colour standards for road signs.	2	For example, different background colours for road signs, which correspond to colours used on maps.
E.10.6	Identify human factors issues in the design of freeway/motorway signs.	2	Consider driver sampling, decision sight distance and information coding.
E.10.7	Describe the methods designers would use to research human factors in signage.	2	Refer to quantitative and qualitative data collection.
E.10.8	Discuss the human factors advantages in LED signs.	3	LED signs may be used as a form of variable message signage, together with optical fibres.
E.10.9	Identify the human factors that are paramount in the design of neon signs.	2	Consider viewing conditions, eye resolution and sensitivity, night-time and daytime viewing.

	Assessment statement	Obj	Teacher's notes
Personal space (1.5 hours)			
E.10.10	Define <i>work-space envelope</i> .	1	
E.10.11	Identify and measure the anthropometric data relevant to the design of a student's workspace envelope when studying at a desk.	2	Consider which parts of the body are relevant for the design, and whether the design is for the minimum, maximum or average measures.
E.10.12	Discuss cultural differences in the sense of personal space.	3	Consider cultural differences, habitual patterns, family spaces, space and relationships.
E.10.13	Suggest how a designer could consider cultural diversity in personal space in the design of a railway carriage.	3	Consider a range of seating arrangements and organization patterns for the carriage furniture, for example, in some countries carriages may carry livestock or personal transport items.
E.10.14	Explain how a designer may incorporate intimate areas into the design of a hotel lounge bar or a cafe.	3	Consider the arrangement of furniture, lighting, music, personal space, colour, textures and decor.

HL E11 Beyond usability—designing for pleasure

2 hours

	Assessment statement	Obj	Teacher's notes
E.11.1	Describe the "four pleasure framework".	2	The "four pleasure framework" was identified by Professor Lionel Tiger from Rutgers University in New Jersey, US. It includes the four areas of physio-pleasure, psycho-pleasure, socio-pleasure and ideo-pleasure.
E.11.2	Define <i>physio-pleasure</i> , <i>socio-pleasure</i> , <i>psycho-pleasure</i> and <i>ideo-pleasure</i> .	1	
E.11.3	Identify ways in which products promote physio-pleasure.	2	Physio-pleasure can be derived from the feel of a product during use (for example, from wearing a silk garment or the smooth feel of an iPod), its taste (for example, from eating chocolate) or its smell (for example, the smell of leather, a new car, coffee, fresh bread from a bread-making machine).
E.11.4	Identify ways in which products promote socio-pleasure.	2	Products and services can facilitate social interaction in a number of ways. E-mail, Internet and mobile phones, for example, facilitate communication between people. Other products may promote social interaction by being conversation starters, for example, jewellery, artwork or furniture. Clothing can communicate social identity and indicate that a person belongs to a particular social group.

	Assessment statement	Obj	Teacher's notes
E.11.5	Identify ways in which products promote psycho-pleasure.	2	In the case of products, this includes issues relating to the cognitive demands of using the product or service and the emotional reactions engendered through the experience of using it. For example, it might be expected that a word processor that facilitated quick and easy accomplishment of, say, formatting tasks would provide a higher level of psycho-pleasure than one with which the user was likely to make many errors. The former word processor should enable the user to complete the task more easily than they would with the latter. The outcome may also be more emotionally satisfying and less stressful.
E.11.6	Identify ways in which products promote ideo-pleasure.	2	Products that are aesthetically pleasing can be a source of ideo-pleasure through appealing to the consumer's tastes. Values could be philosophical or religious or may relate to some particular issue such as the environment or a political movement. These values can be embodied in products. For example, a product made from biodegradable materials might be seen as embodying the value of environmental responsibility.
E.11.7	Explain how the "four pleasure framework" promotes a holistic view of product design and marketing.	3	The "four pleasure framework" is a useful tool for taking a structured approach to product design and marketing. It can act as a practical tool. Using the framework can help to make us more thorough and methodical in our approach than would be the case if we tried to approach the whole thing in an unstructured way.

Glossary

active solar collection	The use of the Sun's energy to heat up water and air directly.
adaptation	A solution to a problem in one field is used to provide a new idea for a design problem in another.
adhesive	An adhesive is a substance that is applied between two surfaces in order to bond them together.
aeration	The incorporation of gas into a food product. It may be air, which is often beaten in, or carbon dioxide, which can be introduced under pressure (for example, to aerated water) or by the action of yeast (for example, in bread).
aesthetic-usability effect	A condition whereby users perceive more aesthetically pleasing designs to be easier to use than less aesthetically pleasing designs.
algorithm	A sequence of instructions to describe a set of actions.
alloy	A mixture that contains at least one metal. This can be a mixture of metals or a mixture of metals and non-metals.
amino acid	In chemistry, an amino acid is any molecule that contains both amino and carboxylic acid functional groups. In biochemistry, this shorter and more general term is frequently used to refer to alpha amino acids in which the amino and carboxylate functionalities are attached to the same carbon, the so-called α -carbon (alpha-carbon).
analogy	The transfer of an idea from one context to another.
animation	The ability to link graphic screens together in such a way as to simulate motion or a process.
anthropometrics	The aspect of ergonomics that deals with body measurements, particularly those of size, strength and physical capacity.
appearance prototype	An appearance prototype, or appearance model, is a physical representation of an object that literally appears like the production product. However, it does not function and is made from wood, foam, clay or other prototyping materials.
appropriate technology	Technology appropriate to the context in which it is applied. Appropriate technologies are low in capital cost, use local materials wherever possible, create jobs using local skills and labour, involve decentralized renewable energy sources, make technology understandable to the people who use it, are flexible, and are not detrimental to quality of life or the environment.
artificial intelligence	A computer-based machine or robot that has the ability to learn from information gained through feedback.
assembly-line production	The mass production of a product via a flow line based on the interchangeability of parts, pre-processing of materials, standardization and work division.

atom	The smallest part of an element that can exist chemically.
attribute listing	Attribute listing identifies the key attributes of a product or process and then enables designers to think of ways to change, modify or improve each attribute.
automation	A volume production process involving machines controlled by computers.
bandwidth	The width of the electromagnetic spectrum that a signal occupies.
batch production	Limited volume production (a set number of items to be produced).
biocompatibility	The property of being biologically compatible by not producing a toxic, injurious or immunological response in living tissue.
biological value	The biological value of a protein refers to how much of the nitrogen content of food is retained by the body. The biological value of proteins ranges from 50% to 100% and is a measure of how much dietary protein source can support growth.
biomechanics	The research and analysis of the mechanics of living organisms.
biomimetics	The application of methods and systems found in nature to the study and design of engineering systems and modern technology.
bit rate	The number of bits per second produced by a digital system.
black water	Water that contains animal, human or food waste and would not be reused for other purposes.
body mass index (BMI)	A measurement of the relative percentages of fat and muscle mass in the human body, in which weight in kilograms is divided by height in metres and the result used as an index of obesity.
“bottom up” modelling	A designer creates part geometry independent of the assembly or any other component. Although there are often some design criteria established before modelling the part, this information is not shared between models. Once all part models are completed, they are brought together for the first time in the assembly.
brainstorming	A form of group think. A group with a recommended size of 10–12 people first devises wild ideas, all of which are written down. No criticism or evaluation is allowed until this is finished, as it is impossible to be creative and critical at the same time. The ideas are then criticized and evaluated.
brand	A brand is a product from a known source (organization). The name of the organization can also serve as a brand.
building envelope	The exterior surface of a building’s construction: the walls, windows, roof and floor. Also referred to as “building shell”.
charge	The quantity of unbalanced electricity in a body (either positive or negative) and construed as an excess or deficiency of electrons and is measured in coulombs.
coagulation of protein	The exposure of a protein to heat or acid, which results in irreversible changes that reduce solubility and change optical characteristics.
composite	A mixture composed of two or more substances (materials) with one substance acting as the matrix or glue.
computer-aided design (CAD)	The use of computers to aid the design process.

computer-aided manufacture (CAM)	The use of computers to aid manufacturing.
computer-integrated manufacture (CIM)	A system of manufacturing that uses computers to integrate the processing of production, business and manufacturing in order to create more efficient production lines.
computer modelling	A computer program that attempts to simulate an abstract model of a particular system.
computer numerical control (CNC)	Refers specifically to the computer control of machines for the purpose of manufacturing complex parts in metals and other materials. Machines are controlled by a program commonly called a "G code". Each code is assigned to a particular operation or process. The codes control X,Y,Z movements and feed speeds.
constructive discontent	Analysing a situation that would benefit from redesign, and working out a strategy for improving it.
convergent thinking	The ability to analyse information in order to select an answer from alternatives.
converging technology	The synergistic merging of nanotechnology, biotechnology, information and communication technologies and cognitive science.
corporate strategy	Long-term aims and objectives of a company and ways of achieving them by allocation of resources.
cost-effectiveness	The most efficient way of designing and producing a product from the manufacturer's point of view.
craft production	A small-scale production process centred on manual skills.
current	The rate of flow of electrons.
data reliability	The completeness and accuracy of a data set that is being used to inform a design decision.
daylighting	The passive solar practice of placing windows, or other transparent media, and reflective surfaces so that, during the day, natural sunlight provides effective internal illumination.
dematerialization	The reduction of weight and use of materials.
demodulation	The process of recovering the information contained, for example, in the human voice, which had been previously added to a suitable electromagnetic carrier.
density	The mass per unit volume of a material.
design for assembly	Designing taking account of assembly at various levels, for example, component to component, components into sub-assemblies and sub-assemblies into complete products.
design for disassembly	Designing a product so that when it becomes obsolete it can easily and economically be taken apart, the components reused or repaired, and the materials recycled.
design for manufacture (DfM)	Designers design specifically for optimum use of existing manufacturing capability.
design for materials	Designing in relation to materials during processing.
design for process	Designing to enable the product to be manufactured using a specific manufacturing process, for example, injection moulding.

die	A tool used in the manufacture of parts by moulding, forging, swaging or stamping processes.
diffusion into the marketplace	The wide acceptance (and sale) of a product.
digital human	Computer simulation of a variety of mechanical and biological aspects of the human body.
disaccharide	A sugar (a carbohydrate) composed of two monosaccharide molecules.
divergent thinking	Using creative ability to produce a wide range of possible solutions to a problem.
diversification	Involves a company both in the development of new products and in selling those products to new companies.
dominant design	The design contains those implicit features of a product that are recognized as essential by a majority of manufacturers and purchasers.
draft angle	The angle of taper, expressed in degrees (usually 5° to 7°), given to the sides of the forging and the side walls of the die impression.
ductility	The ability of a material to be drawn or extruded into a wire or other extended shape.
efficiency	Mechanical efficiency is the effectiveness of a simple machine.
electrical resistivity	This is a measure of a material's ability to conduct electricity. A material with a low resistivity will conduct electricity well.
ergonome	A 2D physical anthropometric model based on a specific percentile, which is used with drawings of the same scale as the model to consider the relationship between the size of an object and people.
ergonomics	The application of scientific information concerning the relationship of human beings to the design of objects, systems and environments.
essential	A compound that cannot be made in the body but has to be provided ready-made in the diet, for example, vitamins, essential fatty acids and essential amino acids.
essential fatty acid	Fatty acids that are required in the human diet. This means that they cannot be synthesized by the body from other fatty acids and must be obtained from food.
expert appraisal	The reliance on the knowledge and skills of an expert in the operation of the product.
exploded isometric drawing	An isometric drawing of an object with more than one component that depicts how the parts of assemblies fit together.
fabric	A material made up of a network of natural or artificial fibres formed by knitting, weaving or pressing into felt.
fashion	A style or trend.
fatty acid	Fatty acids are carboxylic acids with a long hydrocarbon chain, usually straight.
feed speed	The feed speed is the rate at which the cutting tool moves in X, Y and Z paths.
fibre	A class of materials that are continuous filaments or are in discrete elongated pieces, similar to lengths of thread with a length to thickness ratio of at least 80.

fibre structure	A filamentous material long in relation to its width/breadth.
field trial	A test of the performance of some new product under the conditions in which it will be used.
finite element analysis (FEA)	The calculation and simulation of unknown factors in products using CAD systems. For example, simulating the stresses within a welded car part.
fixed costs	The costs that must be paid out before production starts, for example, machinery. These costs do not change with the level of production.
flash	Excess material on a moulded part, forming a thin fan where two parts of the mould meet.
flow chart	A schematic representation of a process.
food allergy	Hypersensitivity to dietary substances.
food hygiene	All aspects of the processing, preparation, storage, cooking and serving of food to make sure that it is safe to eat.
food insecurity	Low levels of food intake, which can be transitory (as a result of crisis), seasonal or chronic (when it occurs on a continuing basis).
food intolerance	An adverse food-induced reaction that does not involve the immune system.
food spoilage	Food becoming unfit for consumption, for example, due to chemical or biological contamination.
freehand drawing	The spontaneous representation of ideas on paper without the use of technical aids.
functional prototype	A functional prototype, or functional appearance model, is a prototype that “looks like” and “works like” a production product. Although they are made from prototype materials, these models simulate actual finishes and colours as well as mechanisms.
G code	Coordination-based code that also includes feed speed and stop/start.
gelatinizing (gelling)	The formation of a gel by using gelatin or by the heat-treatment of starch and water to break open the starch granules, for example, custard.
genetically modified organism	A plant or animal in which the DNA has been altered through the insertion of genetic material from another source. Genetic modification is most often used in agricultural crops to increase the resistance to herbicides or to engineer pesticides into crops.
glycerol	A sugar alcohol with three hydrophilic alcoholic hydroxyl groups. It is an important component of triglycerides (fats and oils) and phospholipids.
green design	Designing in a way that takes account of the environmental impact of the product throughout its life.
grey water	Waste water generated from processes such as washing dishes, bathing and laundry.
haptic technology	Haptic technology is an emerging technology that interfaces the user via the sense of touch.
hardness	The resistance a material offers to penetration or scratching.
human development index	A comparative measure of poverty, literacy, education, life expectancy, childbirth and other factors for countries worldwide.

ideo-pleasure	Pleasure derived from satisfying people's tastes, values and aspirations.
incremental design	Small changes to the design of a product that seem trivial but the cumulative effect of which over a longer period can be very significant.
industrial robot	A flexible computer-operated machine that is able to perform a range of tasks in an efficient and accurate manner.
injection moulding	The direct introduction of molten plastic under pressure into a die, which then cools rapidly, allowing the formed object to be released from the mould.
innovation	The business of putting an invention in the marketplace and making it a success.
intelligent building	Intelligent buildings apply technologies to improve the building environment and functionality for occupants and tenants while controlling costs to improve end-user security, comfort and accessibility and help user productivity.
intelligent fabric	A fabric with technology-enhanced performance used in smart clothing, for example, enhanced stain resistance, breathability or incorporating input sensors.
invention	The process of discovering a principle. A technical advance in a particular field often resulting in a novel product.
isometric drawing	A 3D representation of an object drawn with the horizontal plane at 30° to the vertical plane.
just-in-case (JIC)	A situation where a company keeps a small stock of components (or complete items) or ones that take a long time to make, just in case of a rush order.
just-in-time (JIT)	A situation where a firm does not allocate space to the storage of components or completed items, but instead orders them (or manufactures them) when required. Large storage areas are not needed and items that are not ordered are not made.
life cycle analysis	The assessment of the effect a product has on the environment from the initial concept to disposal.
lifestyle	The way a person or group lives, including patterns of social relations, consumption, entertainment and dress.
lipid	An organic compound that contains aliphatic hydrocarbons, essential for the structure and function of living cells. Examples include fats, waxes and steroids.
literature search	The use of consumer reports and newspaper items to follow historical development. Useful sources of information could include CD-Roms, such as encyclopedias and newspapers, or more specific disks, subject-specific magazines and manufacturers' information.
living building	Houses and offices designed to function like living organisms, specifically adapted to place and able to draw all of their requirements for energy and water from the surrounding sun, wind and rain.
lone inventor	An individual working outside or inside an organization who is committed to the invention of a novel product and often becomes isolated because he or she is engrossed with ideas that imply change and are resisted by others.

machine tool step variable	This applies to 3D profiling. It is the amount of tool that passes over work already cut and determines the quality of the finished surface. It is expressed as a percentage—the higher the quality, the higher the percentage.
malnutrition	The physiological condition resulting from inadequacy or imbalance in food intake or from poor absorption of food consumed.
manikin	An anatomical 3D model of the human body.
manufacturing technique	A specific manufacturing term, sometimes relating to one material group only.
market development	Finding new applications for existing products, thereby opening up new markets.
market penetration	Increasing sales to existing customers or finding new customers for an existing product.
market pull	The initial impetus for the development of a new product is generated by a demand from the market.
market sector	A broad way of categorizing the kinds of market the company is aiming for.
market segmentation	Markets divide up into smaller segments where the purchasers have similar characteristics and tastes.
mass customization	A sophisticated CIM system that manufactures products to individual customer orders. The benefits of economy of scale are gained whether the order is for a single item or for thousands.
mass production	The production of large amounts of standardized products on production lines, permitting very high rates of production per worker.
mathematical model	A model using mathematical symbols that can be manipulated numerically.
mechanical advantage	This is the factor by which a machine multiplies the force put into it.
mechanization	A volume production process involving machines controlled by humans.
micronutrient deficiency	Lack of essential vitamins and minerals resulting from unbalanced food intake and specific problems of food absorption.
minerals	Natural compounds formed through geological processes.
modulation	The process of adding the information contained, for example, in the human voice to a suitable electromagnetic carrier.
molecule	Two or more atoms that are normally bonded together covalently.
monosaccharide	The simplest form of carbohydrate, consisting of one sugar residue. They are the building blocks of disaccharides and polysaccharides.
morphological synthesis	Morphological synthesis is an elaboration of attribute listing. After completing the list of attributes, list them along two sides of a 2D grid. Think creatively about how the attributes can be developed through new ideas in each of the cells to improve the design.
motion capture technology	The recording of human and animal movement by any means, for example, by video, magnetic or electro-mechanical devices.
multiplexing	To combine multiple signals for transmission over a single line or medium.

nanotechnology	Refers to materials and devices that operate at the nanoscale. "Nano" means a billionth (1/1000,000,000). A nanometre is one-billionth of a metre.
negative saturation	The most negative voltage the operational amplifier can output (–13 V).
non-renewable resources	A natural resource that cannot be re-made or re-grown as it does not naturally re-form at a rate that makes its use sustainable, for example, coal, petroleum and natural gas.
numerical control (NC)	Automated machines that require data to be inputted manually by a trained operator.
obesity	Obesity is defined as an excessively high amount of body fat in relation to lean body mass. A body mass index of more than 30 is defined as obese by the World Health Organization.
one-off production	An individual (often craft-produced) article or a prototype for larger-scale production.
organoleptic	Involving the use of sense organs.
orthographic drawing	A series of flat views of an object showing it exactly as it is in shape and size.
overweight	Overweight refers to increased body weight in relation to height, when compared to some standard of acceptable or desirable weight. A body mass index of more than 25 is defined as overweight by the World Health Organization. Overweight may or may not be due to increases in body fat.
paper prototyping	Representative users perform realistic tasks by interacting with a paper version of the user–product interface that is manipulated by a person acting as a computer, who does not explain how the interface works.
parison	A short length of extruded pipe for use in blow moulding.
passive solar design	The technique of heating and cooling a building naturally without the use of mechanical equipment.
percentile range	That proportion of a population with a dimension at or less than a given value.
performance test	An evaluation of the actual performance of the task or learning objective using the conditions under which it will be performed and the absolute standard for acceptable performance.
permanent joining techniques	A permanent join is a type of fastening that is not supposed to be removed. It is only possible to remove such joins by drilling, cutting or grinding the join away.
perspective drawing	A 3D drawing that realistically represents an object by utilizing foreshortening and vanishing points (usually imaginary ones).
physio-pleasure	Pleasure derived from the sensory organs, including pleasures connected with touch, taste, smell and sensual pleasure.
planned obsolescence	A conscious act either to ensure a continuing market or to ensure that safety factors and new technologies can be incorporated into later versions of the product.
plastic deformation	The permanent deformation of a solid subjected to a stress.

polysaccharide	A polymer comprising many monosaccharide molecules joined by glycosidic links. For example, starch and cellulose.
population stereotypes	Responses that are found to be widespread in a user population.
positive saturation	Positive saturation is the most positive voltage an operational amplifier can output (+13 V).
poverty	Deprivation of essential goods and services, for example, food, clothing, shelter and education, and a lack of sufficient income and wealth.
product champion	An influential individual, usually working within an organization, who develops an enthusiasm for a particular idea or invention and “champions” it within that organization.
product development	The creation of new, modified or updated products aimed mainly at a company’s existing customers.
product family	A group of products having common classification criteria. Members normally have many common parts and assemblies.
product stewardship	Everyone involved in making, selling, buying or handling electronic equipment takes responsibility for minimizing environmental impact of the equipment at all stages in the life cycle.
programmable interface controller (PIC)	Microchips that can be programmed by a computer to simulate an integrated circuit. Having been programmed they can be disconnected from the computer and used in electronic projects to recognize a range of inputs and to control the project.
prosthesis	An artificial limb, tooth or other part of the body manufactured to take the place of a missing or dysfunctional one.
protein	A complex, high-molecular-weight, organic compound consisting of an amino acid joined by a peptide bond. Proteins make up the constituents of biological organisms.
psycho-pleasure	Pleasure derived from people’s mental and emotional reactions to a product.
quality assurance	This covers all activities from design to documentation. It also includes the regulation of quality of raw materials, assemblies, products and components, services related to production, and management and inspection processes.
quality control	Involved in development systems to ensure that products or services are designed and produced to meet or exceed customer requirements and expectations.
radical design	Where a completely new product is devised by going back to the roots of a problem and thinking about a solution in a different way.
reconditioning	Rebuilding a product so that it is in an “as new” condition, and is generally used in the context of car engines and tyres.
recycling	Recycling refers to using the materials from obsolete products to create other products.
refresh rate	How frequently (per second) an image is captured and transmitted.
renewable resources	Resources that are naturally replenished in a short time.
repair	The reconstruction or renewal of any part of an existing structure or device.

resistance	The opposition that a substance offers to the flow of electric current.
resolution	A measure of the clarity of an image captured.
reuse	Reuse of a product in the same context or in a different context.
robust design	Flexible designs that can be adapted to changing technical and market requirements.
saturated fatty acid	A fatty acid in which no double bonds are present between the carbons of the fatty acid chains.
service costs	The cost required to maintain or repair a product or system.
socio-pleasure	Pleasure from relationships with others, for example, specific relationships with friends, loved ones, colleagues or like-minded people or with society as a whole when it is related to status and self-image.
solid modelling	Solid models are clear representations of the final part. They provide a complete set of data for the product to be realized.
sprue	This is the passage through which a liquid material flows into a die, where it solidifies to form parts.
stiffness	The resistance of an elastic body to deflection by an applied force.
sublimation printing process	A two-step process in which paper is first printed with sublimation dyes and then heat and pressure are applied to the paper so that the image is transferred to another material, for example, fabric.
surface modelling	A realistic picture of the final model, offering some machining data. Surface models contain no data about the interior of the part.
sustainable development	Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.
technocautious	Someone who needs some convincing before embracing technological change.
technology push	Where the impetus for a new design emanates from a technological development.
technophile	Someone who immediately welcomes a technological change.
technophobe	Someone who resists all technological change.
tensile strength	The ability of a material to withstand pulling forces.
thermal conductivity	A measure of how fast heat is conducted through a slab of material with a given temperature difference across the slab.
thermal expansion (expansivity)	A measure of the degree of increase in dimensions when an object is heated. This can be measured by an increase in length, area or volume. The expansivity can be measured as the fractional increase in dimension per kelvin increase in temperature.
time constant	The time required for the current or voltage in a circuit to rise or fall exponentially through approximately 63% of its amplitude.
“top down” modelling	“Top down” design is a product development process obtained through 3D, parametric and associative CAD systems. The main feature of this new method is that the design originates as a concept and gradually evolves into a complete product consisting of components and sub-assemblies.

torque	“Rotational force” commonly measured in units of newton metres.
toughness	The ability of a material to resist the propagation of cracks.
triple bottom line sustainability	An expanded spectrum of values and criteria for measuring organizational success: economic, environmental and social.
undernourishment	Chronic food insecurity in which food intake is insufficient to meet basic energy requirements on a continuing basis.
undernutrition	Result of prolonged low level of food intake and/or poor absorption of food consumed. Manifestations include wasting, stunting or underweight, reduced cognitive ability, poor health status and low productivity.
unsaturated fatty acid	One in which there are double bonds present between the carbons of the fatty acid chains.
upgradeability	How easily a system or product can be upgraded, that is, its performance enhanced.
user population	The range of users for a particular product or system.
user research	Obtaining users’ responses.
user trial	The observation of people using a product and collection of comments from people who have used a product.
<i>U</i> value	A measure of the thermal conductance of a material. The higher the <i>U</i> value, the greater the conduction.
value for money	The relationship between what something, for example, a product, is worth and the cash amount spent on it.
variable costs	Costs that vary with output, for example, fuel or raw materials.
velocity ratio	A measurement of force amplification.
virtual reality	The ability to simulate a real situation on the screen and interact with it in a near-natural way.
vitamins	Organic molecules required by a living organism in minute amounts, but which the organism cannot synthesize.
voltage	The difference in electrical potential between two points.
water activity (a_w)	The water in food that is not bound to food molecules, which can support the growth of bacteria, yeasts and fungi, and is measured on a scale of 0 (bone dry) to 1.0 (pure water).
work-space envelope	A 3D space within which you carry out physical work activities when you are at a fixed location.
yarn	A long continuous length of interlocked synthetic or natural fibres.
Young’s modulus	The stiffness of a material.

Mathematical requirements

It is assumed that students will be competent in the techniques listed below. Students will not be expected to remember any equations. All equations will be provided in the examination paper.

All Diploma Programme design technology students should be able to:

- perform basic arithmetic functions and understand/recognize basic geometric shapes
- make simple calculations and approximations within an appropriate context involving averages (means), decimals, fractions, percentages, ratios, approximations, reciprocals and scaling
- take account of accuracy in calculations, handling them so that significant figures are neither lost unnecessarily nor carried out beyond what is justified
- express fractions as percentages and vice versa
- recognize and use expressions in decimal and standard form notation
- use logarithms to base 10, powers, roots, reciprocals, direct proportion and inverse proportion
- solve simple algebraic equations, given the appropriate formula
- comprehend the meanings of, and use, common mathematical symbols and/or notations
- display and interpret frequency data in the form of bar charts, column graphs and histograms, and interpret pie charts and nomograms
- select suitable scales and axes, plot and interpret graphs involving two variables that show linear and non-linear relations
- plot and interpret scatter diagrams to identify a correlation between two variables, and appreciate that the existence of a correlation does not establish a causal relationship
- select appropriate variables and scales for plotting a graph, especially to obtain a graph of the form $y = mx + c$
- determine and interpret the slope and intercept of linear graphs, and extrapolate graphs
- use simple geometric drawings to measure lengths or angles.

